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**Marks et al.**

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(54) **ADVANCED TECHNOLOGY FRAME  
STRUCTURE WITH BACKWARD  
COMPATIBILITY**

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(57) **ABSTRACT**

An advanced technology frame structure is described herein. The advanced technology frame structure can enhance a first technology frame structure in dimensions of time, frequency, or a combination of time and frequency. A second technology frame structure time division multiplexes second technology subframes with the first technology downlink and uplink subframes. The first technology downlink subframe can be divided into a first technology downlink subframe and one or more second technology downlink subframes. Similarly, the first technology uplink subframe can be divided into a first uplink subframe and one or more second technology uplink subframes. These principles can be expanded upon and can be applied in many communication systems.

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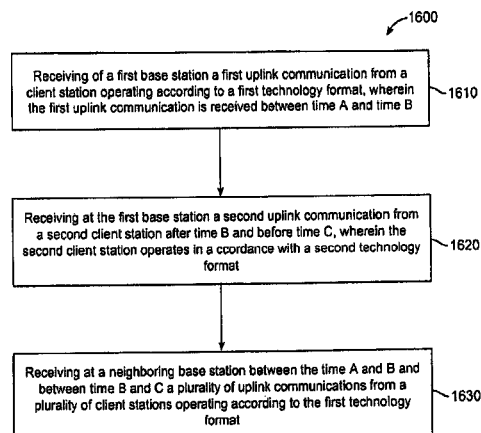
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on Feb. 20, 2008.

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**28 Claims, 21 Drawing Sheets**



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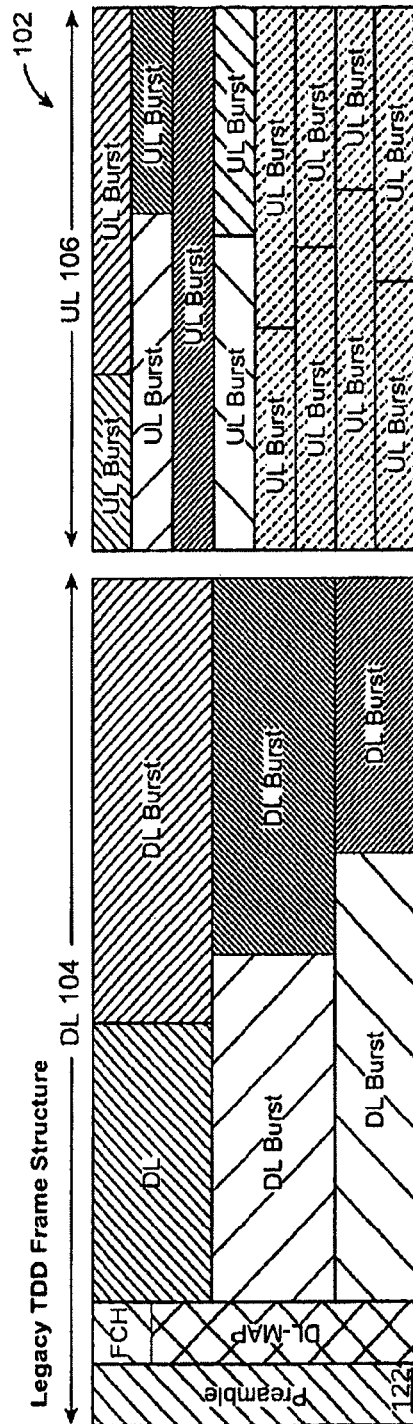


FIG. 1a

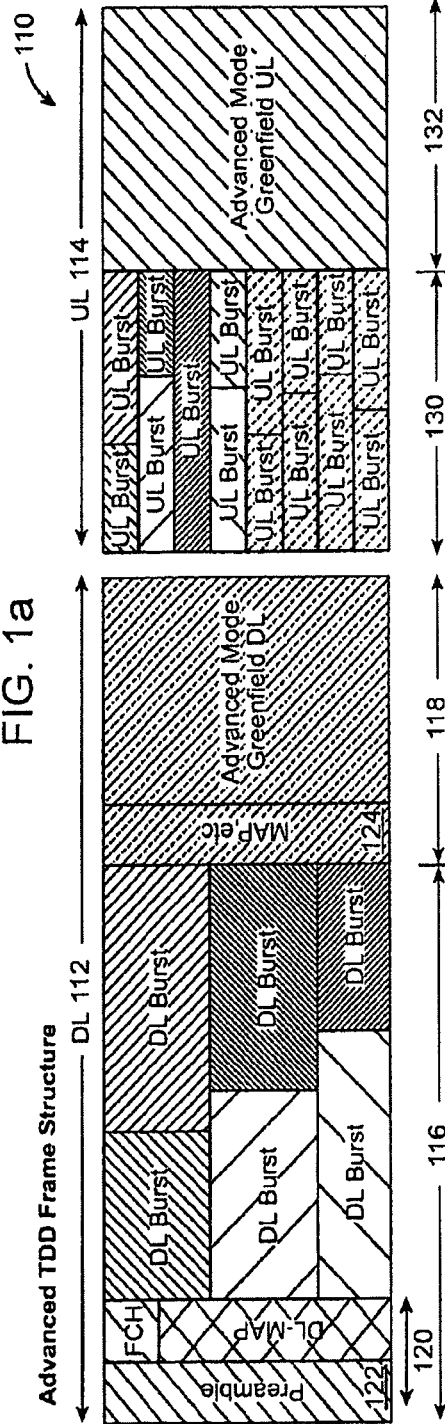
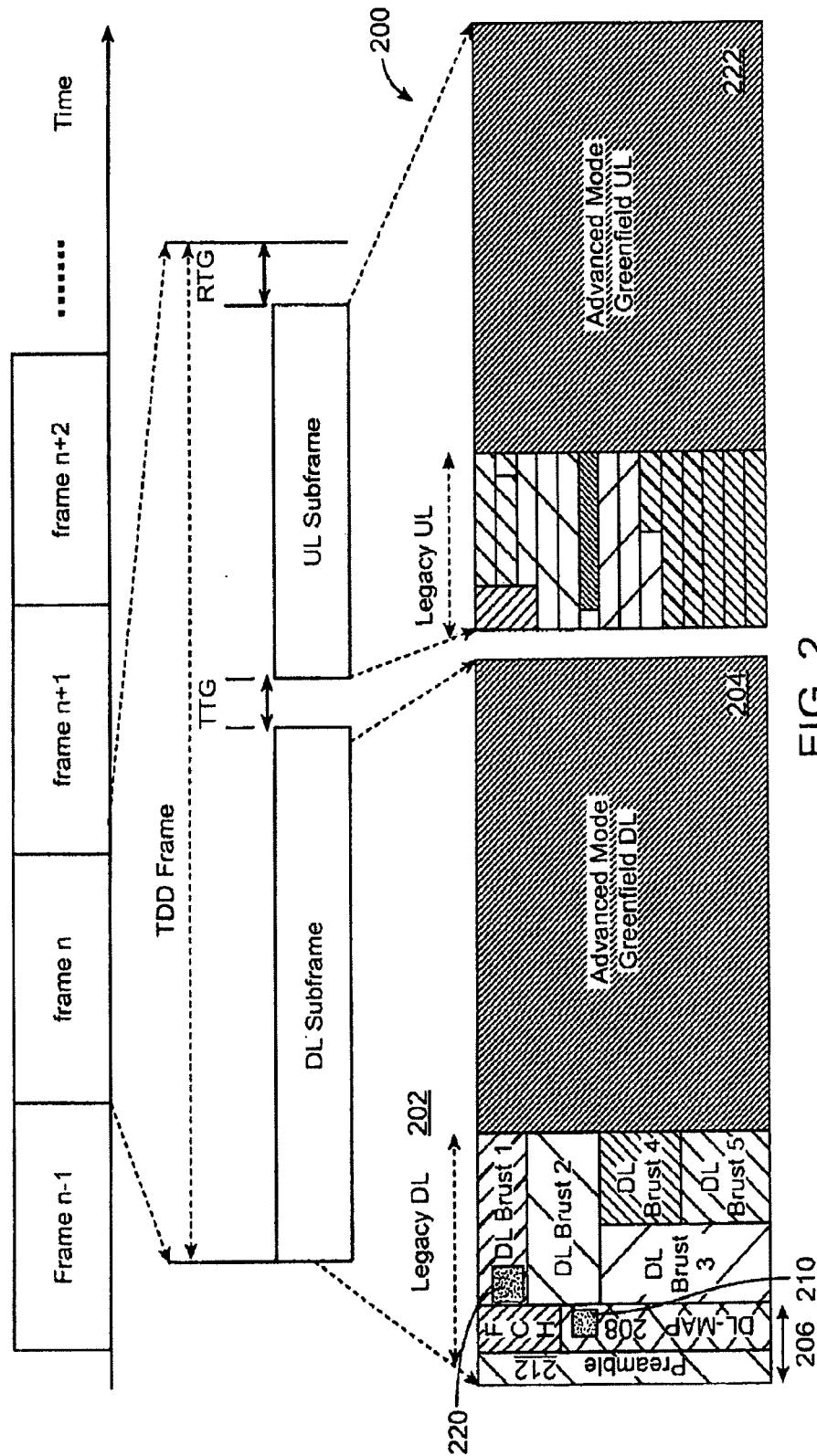


FIG. 1b



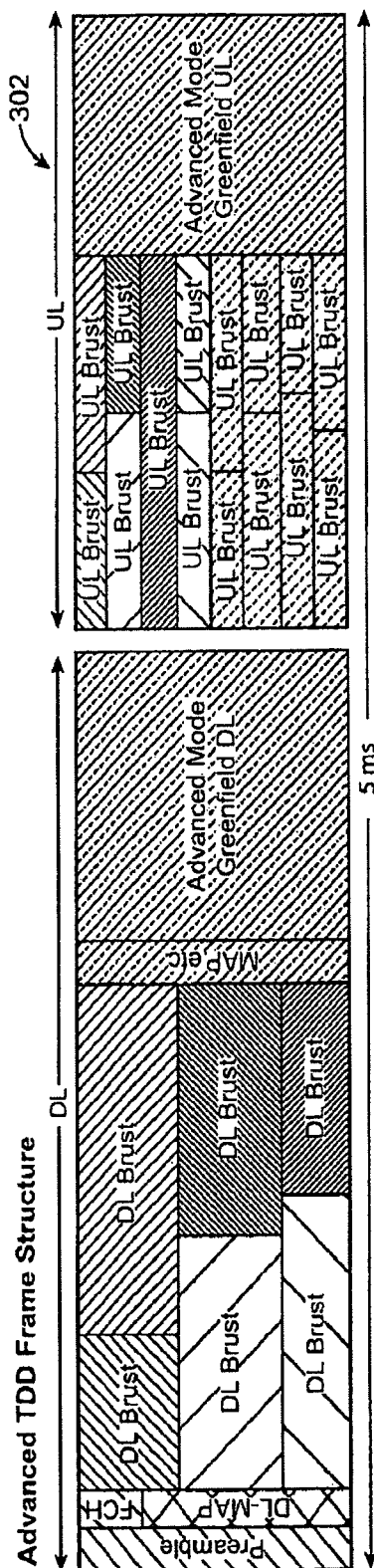


FIG. 3a

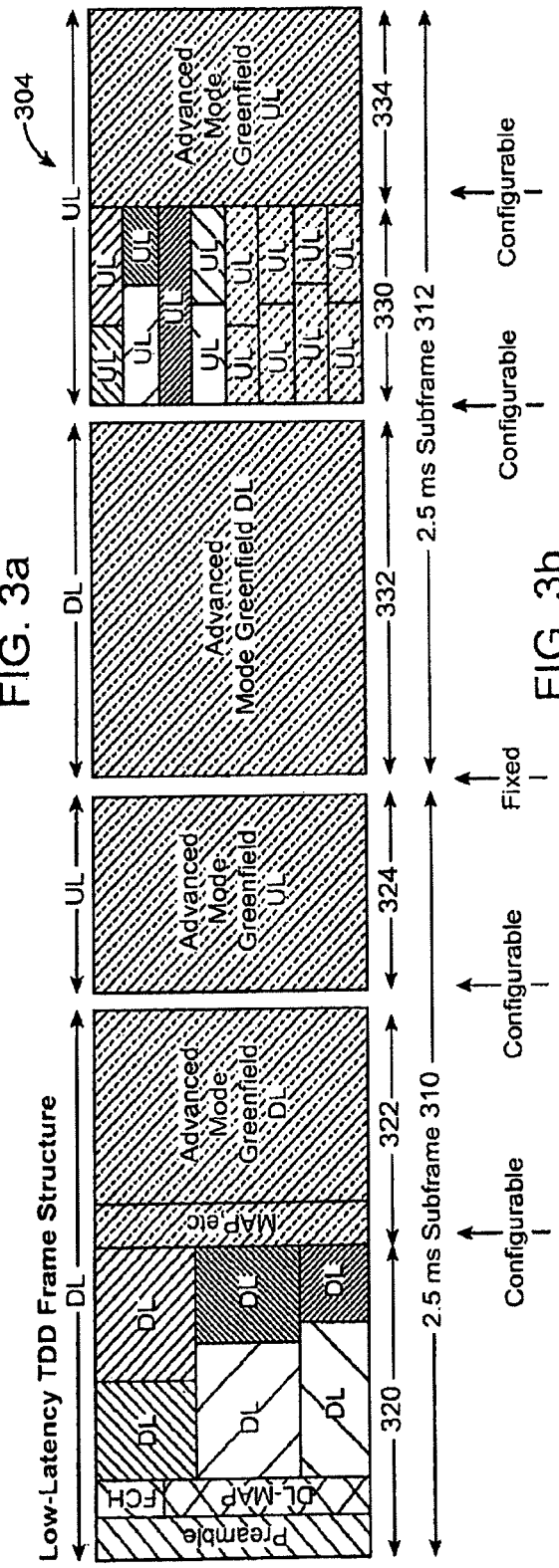


FIG. 3b

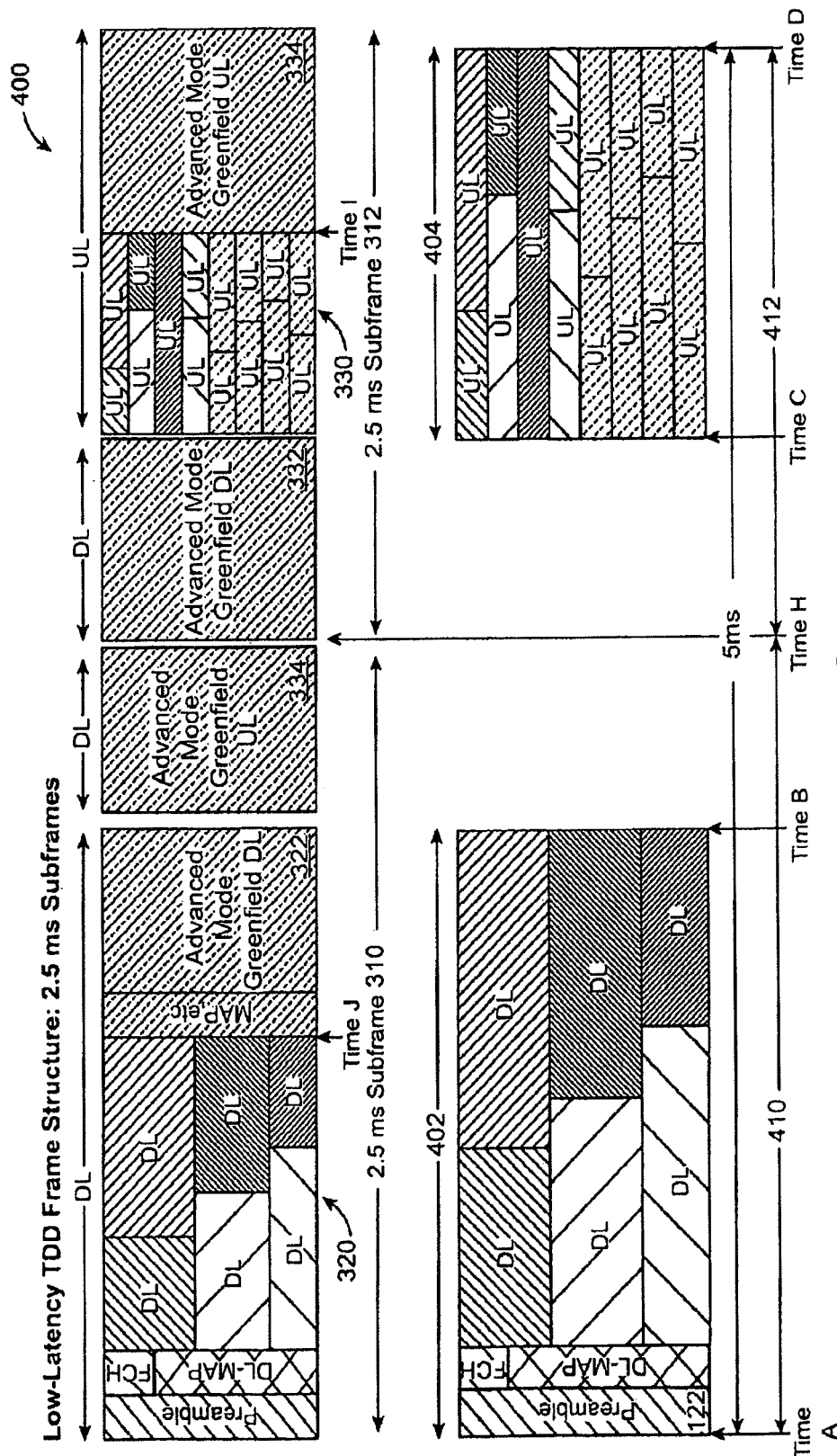


FIG. 4

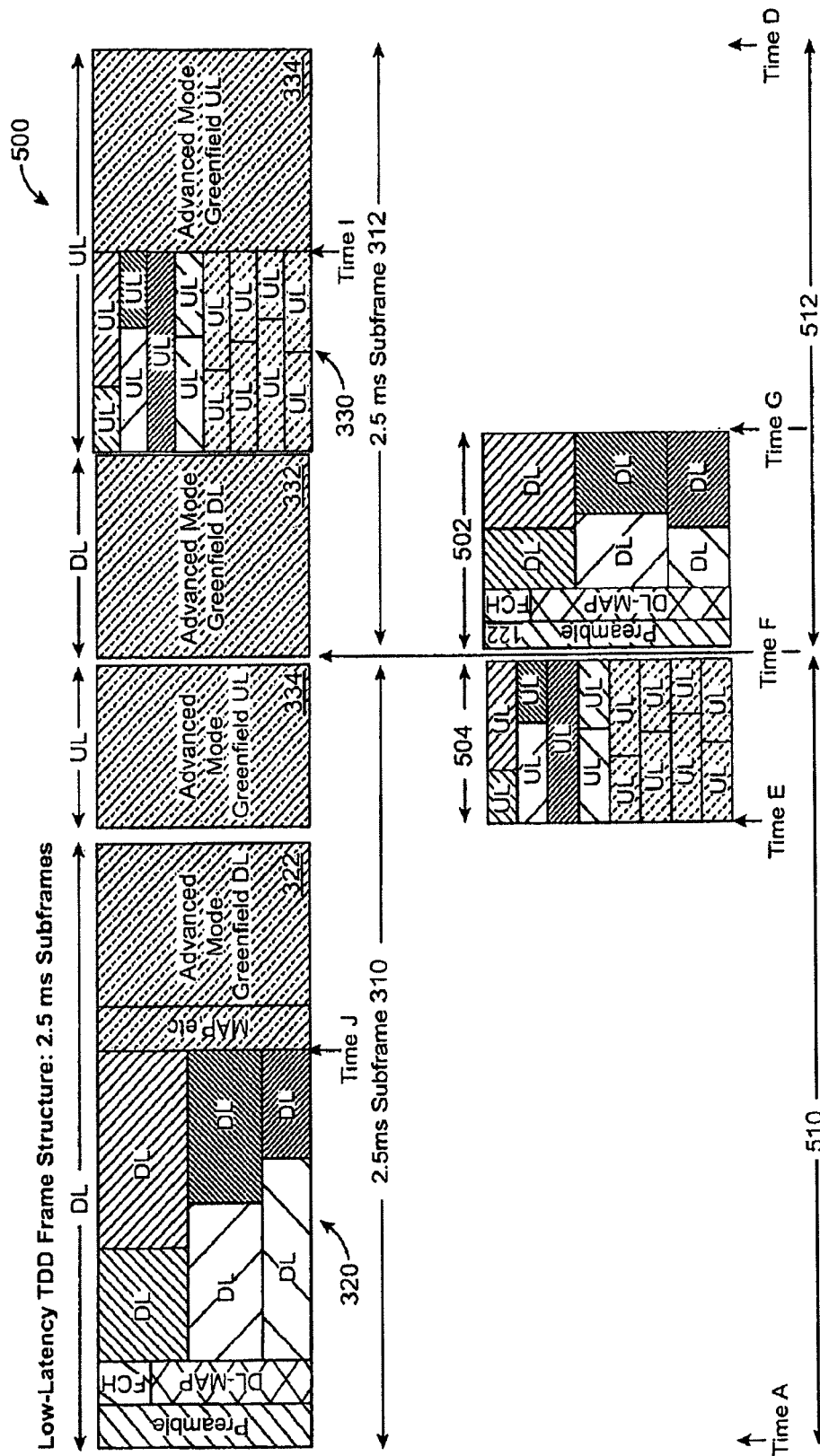
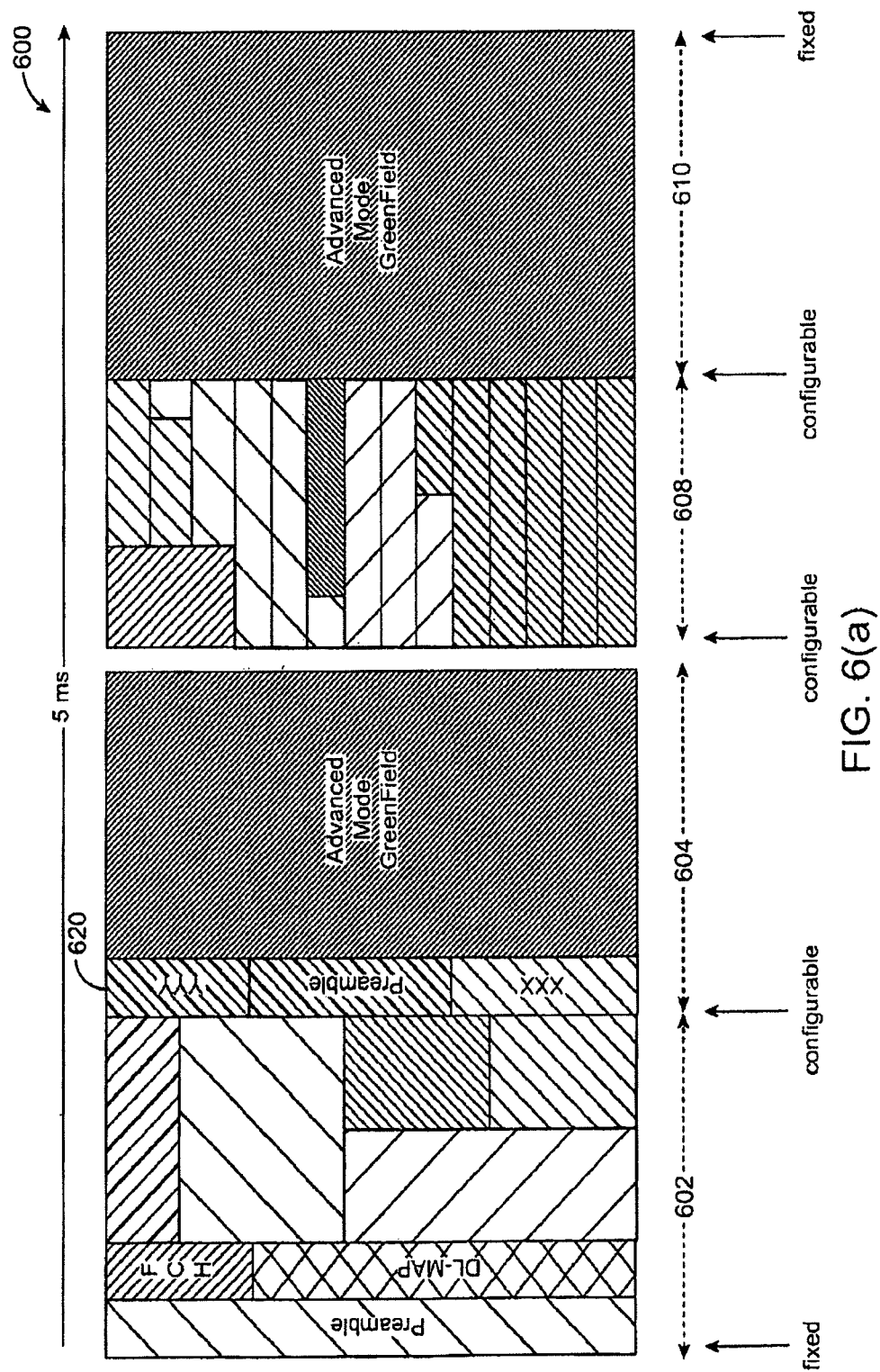


FIG. 5





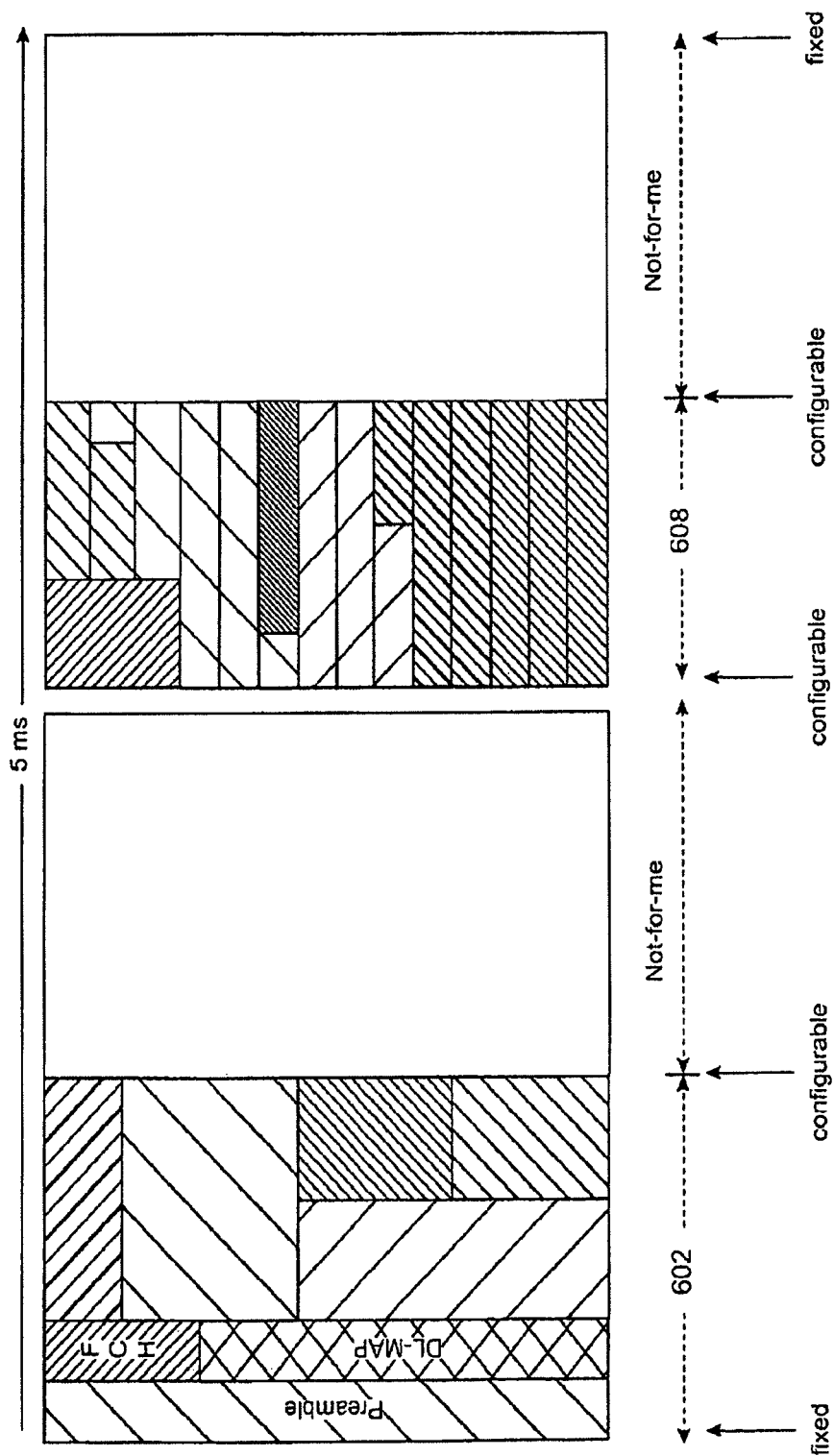


FIG. 6(b)

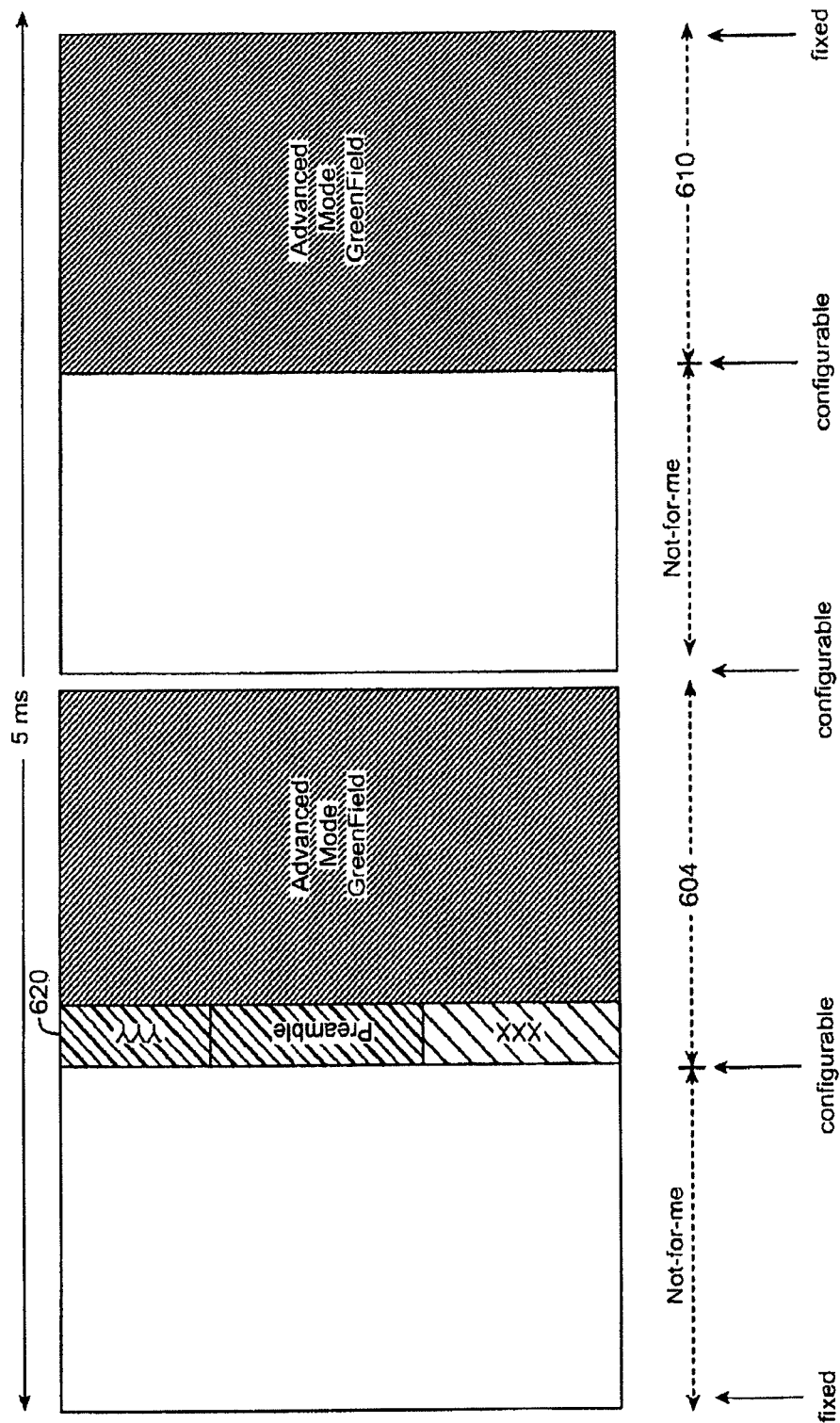


FIG. 6(c)

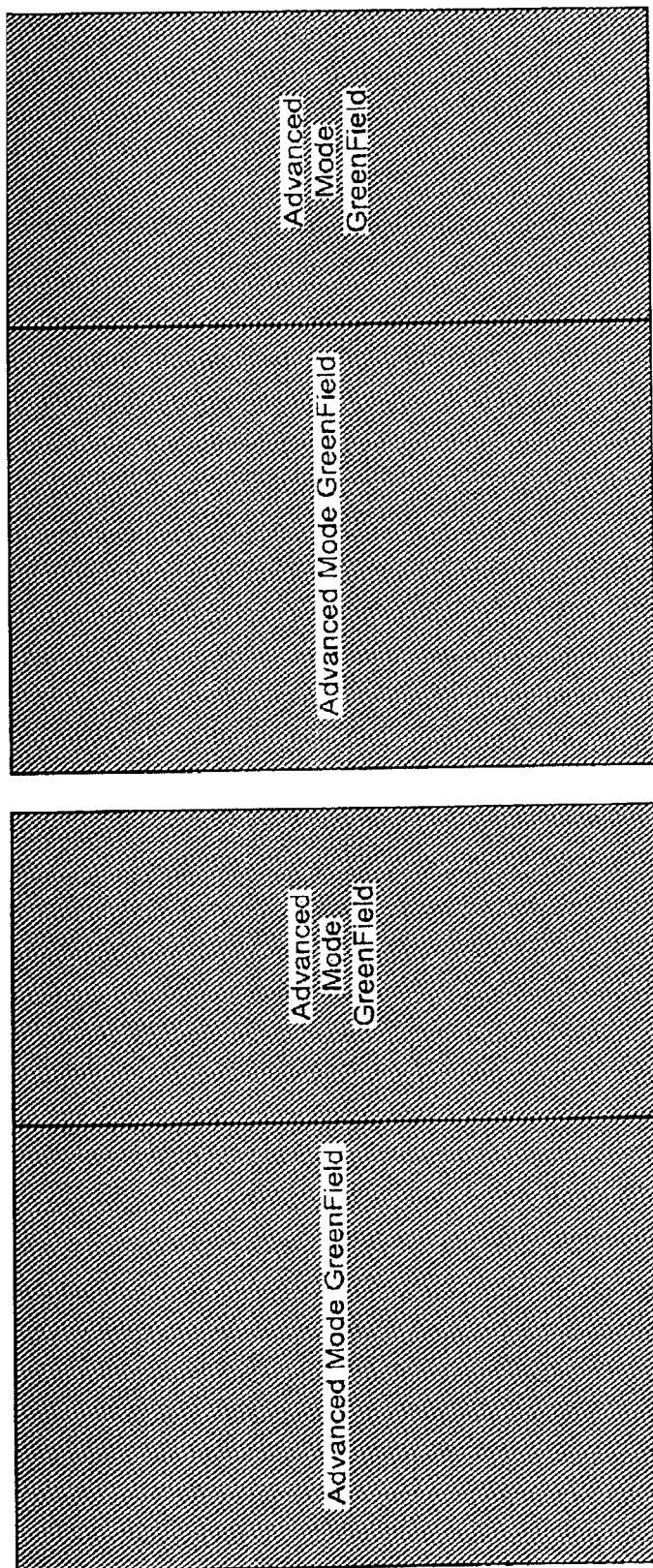


FIG. 6(d)

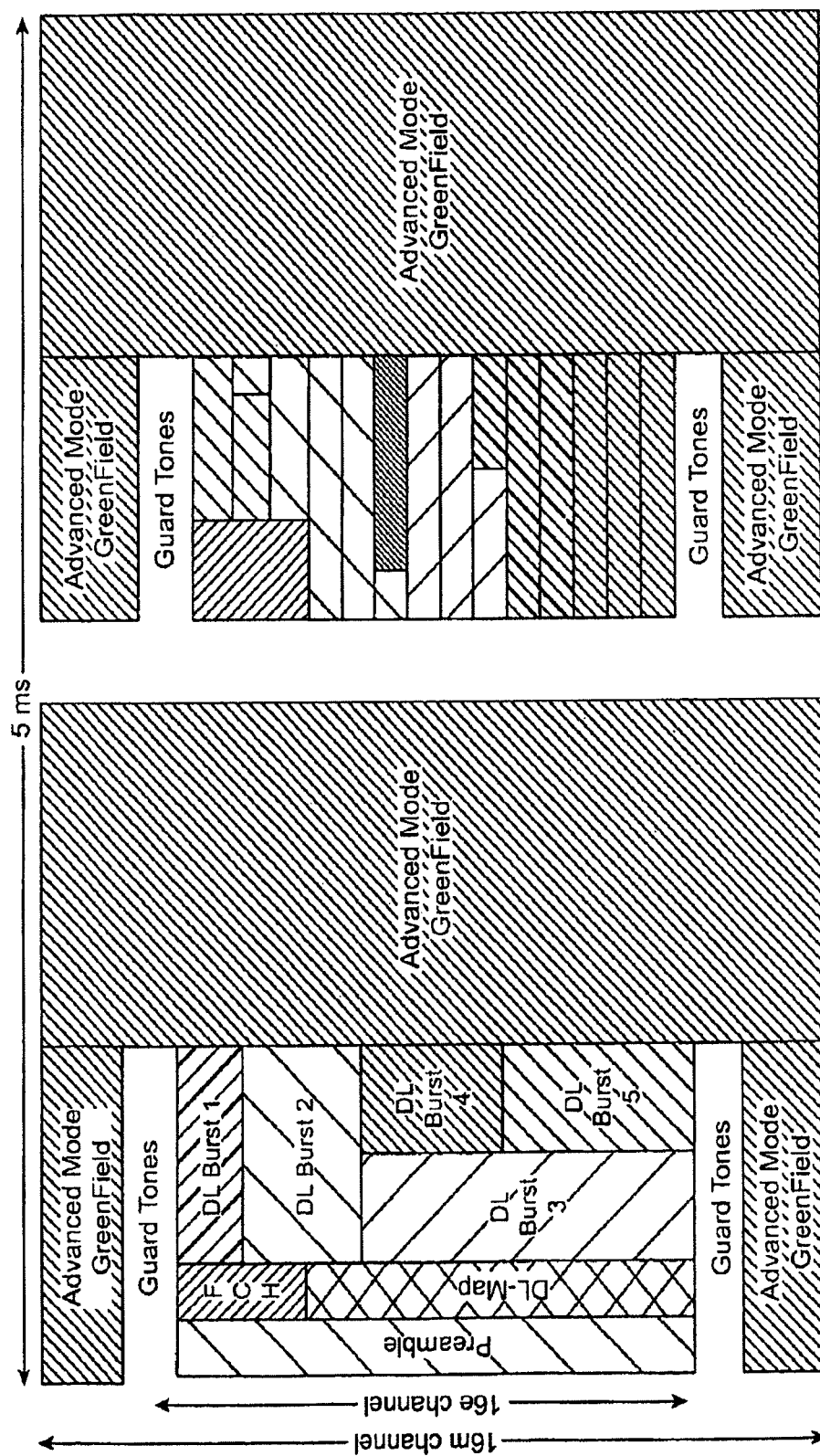


FIG. 7(a)

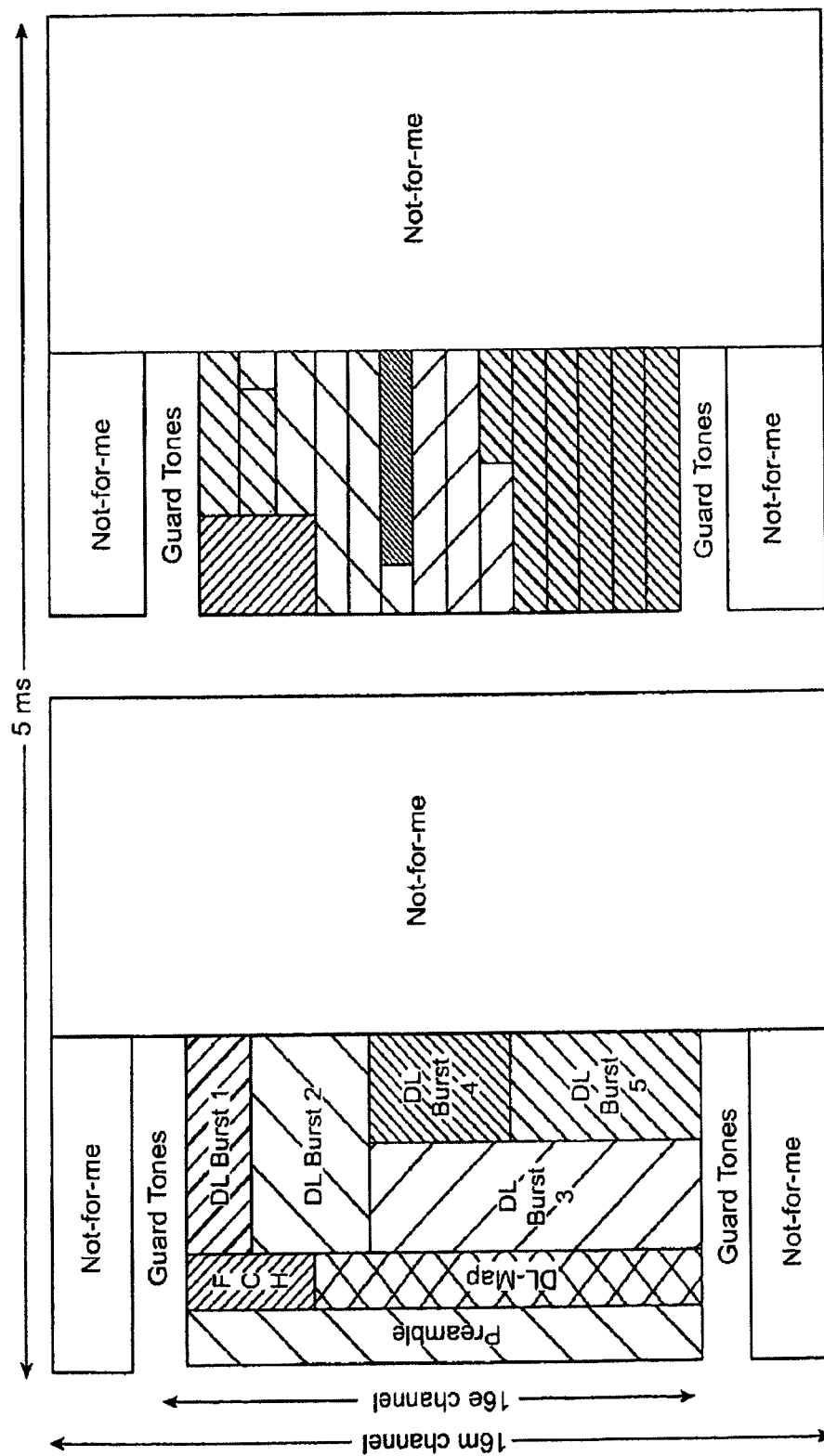


FIG. 7(b)

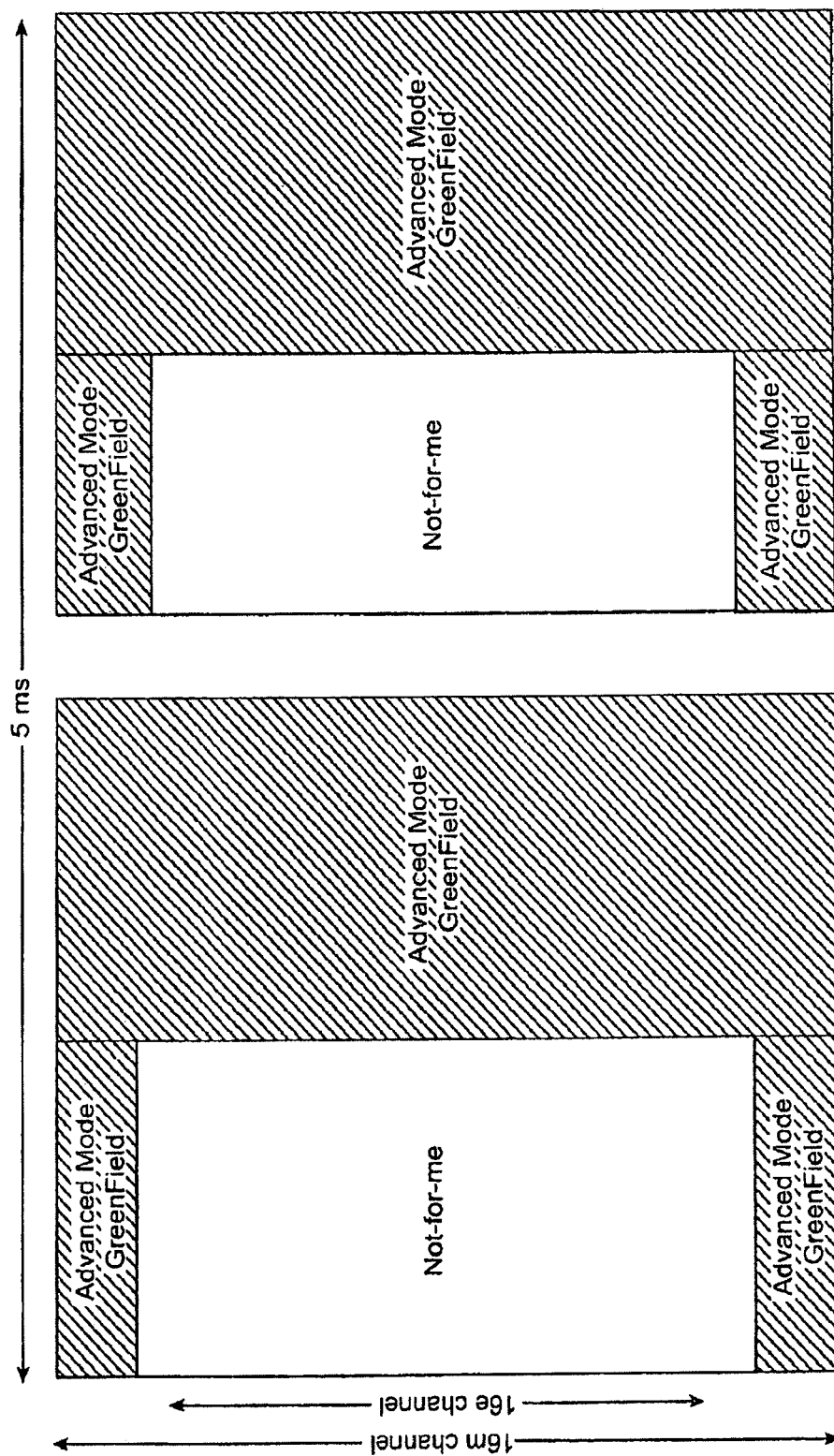


FIG. 7(c)

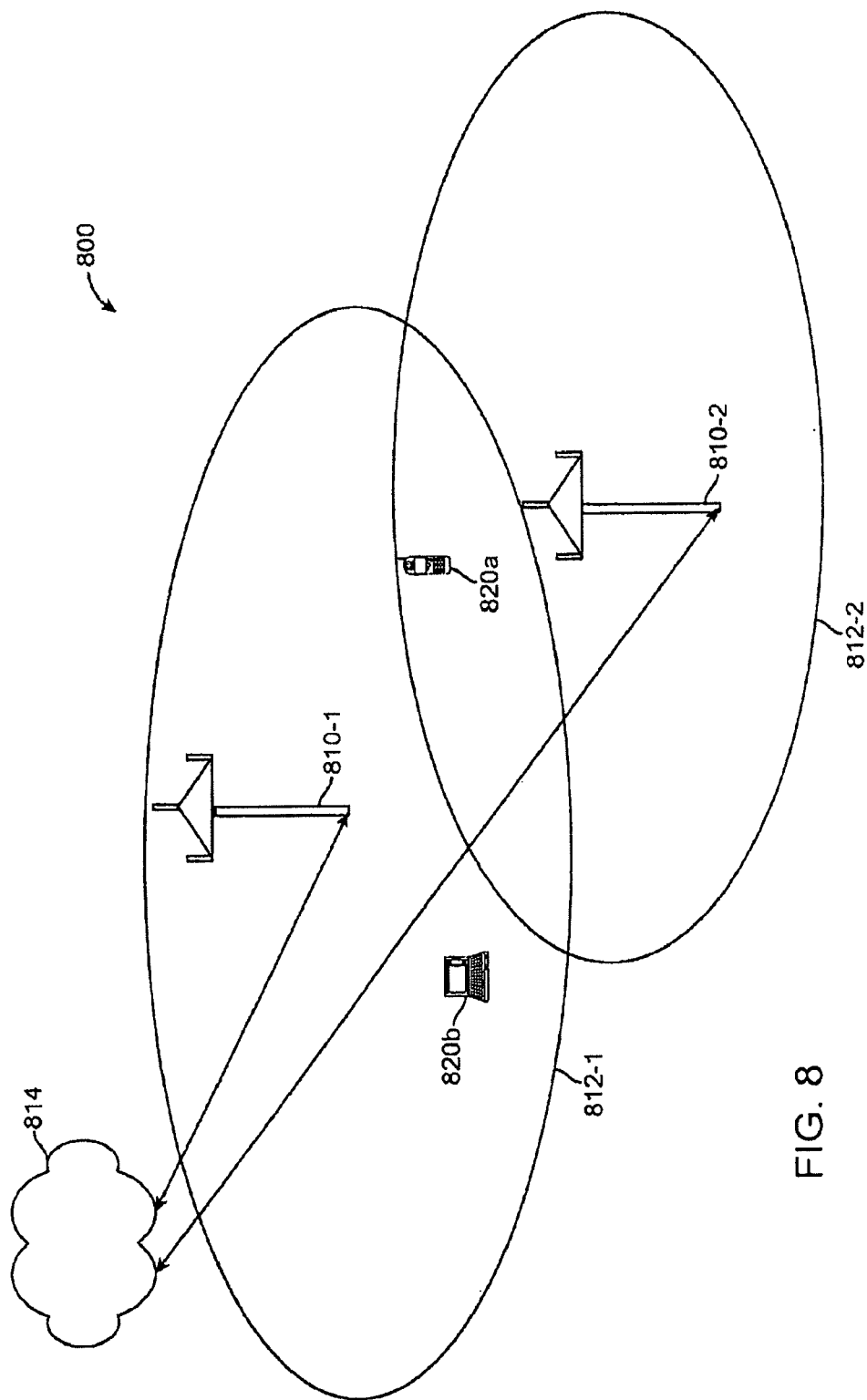
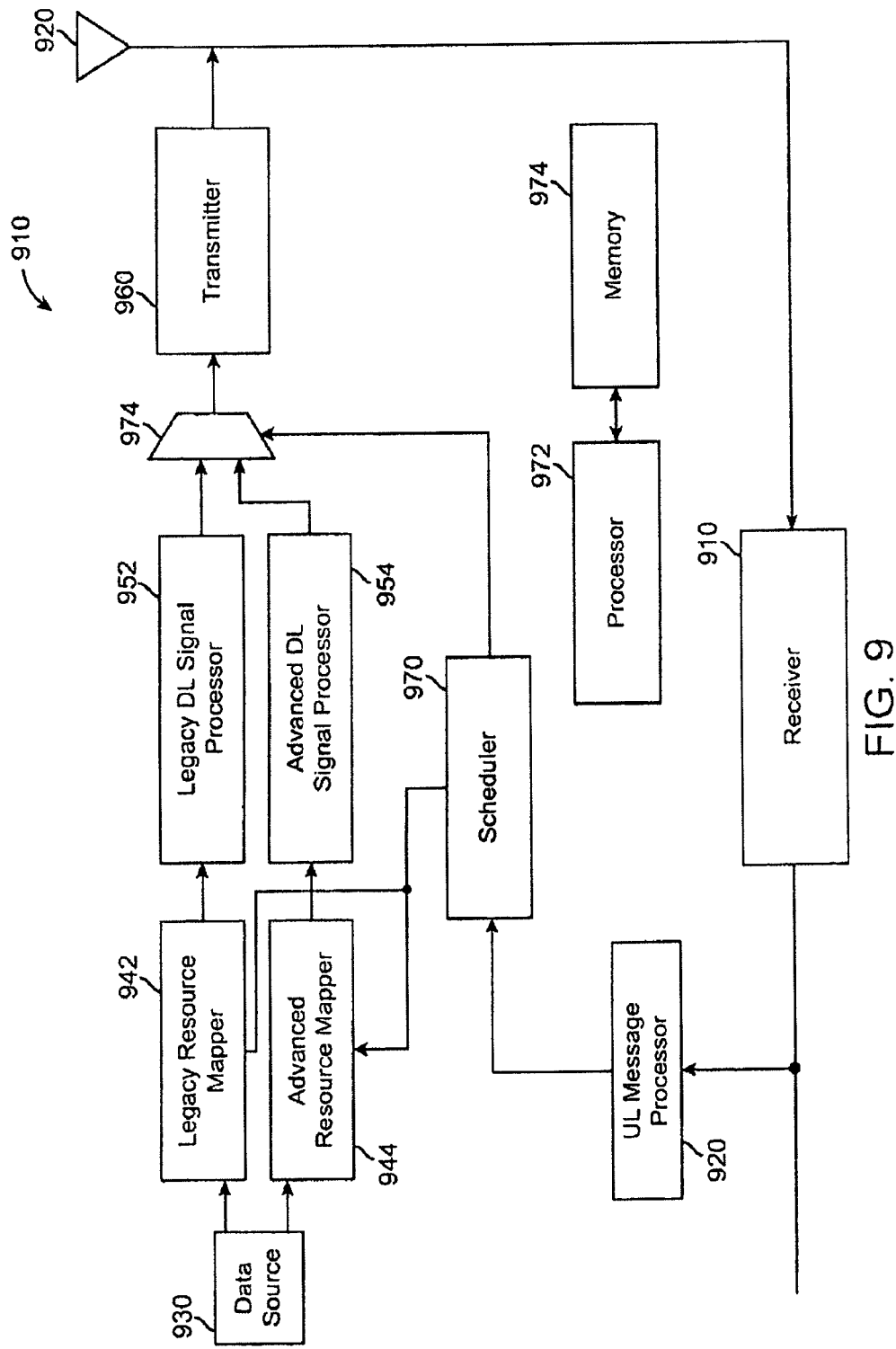


FIG. 8





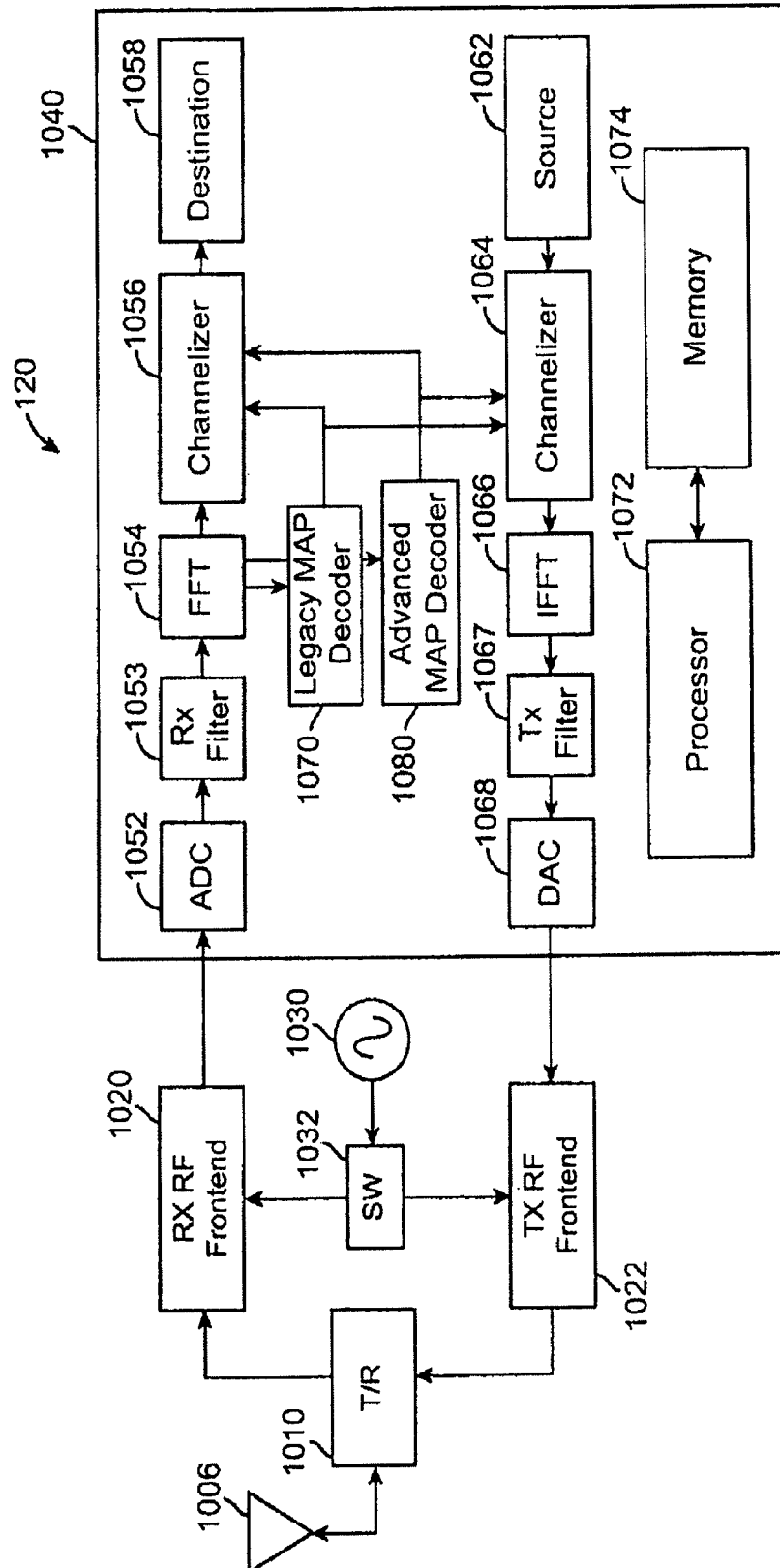
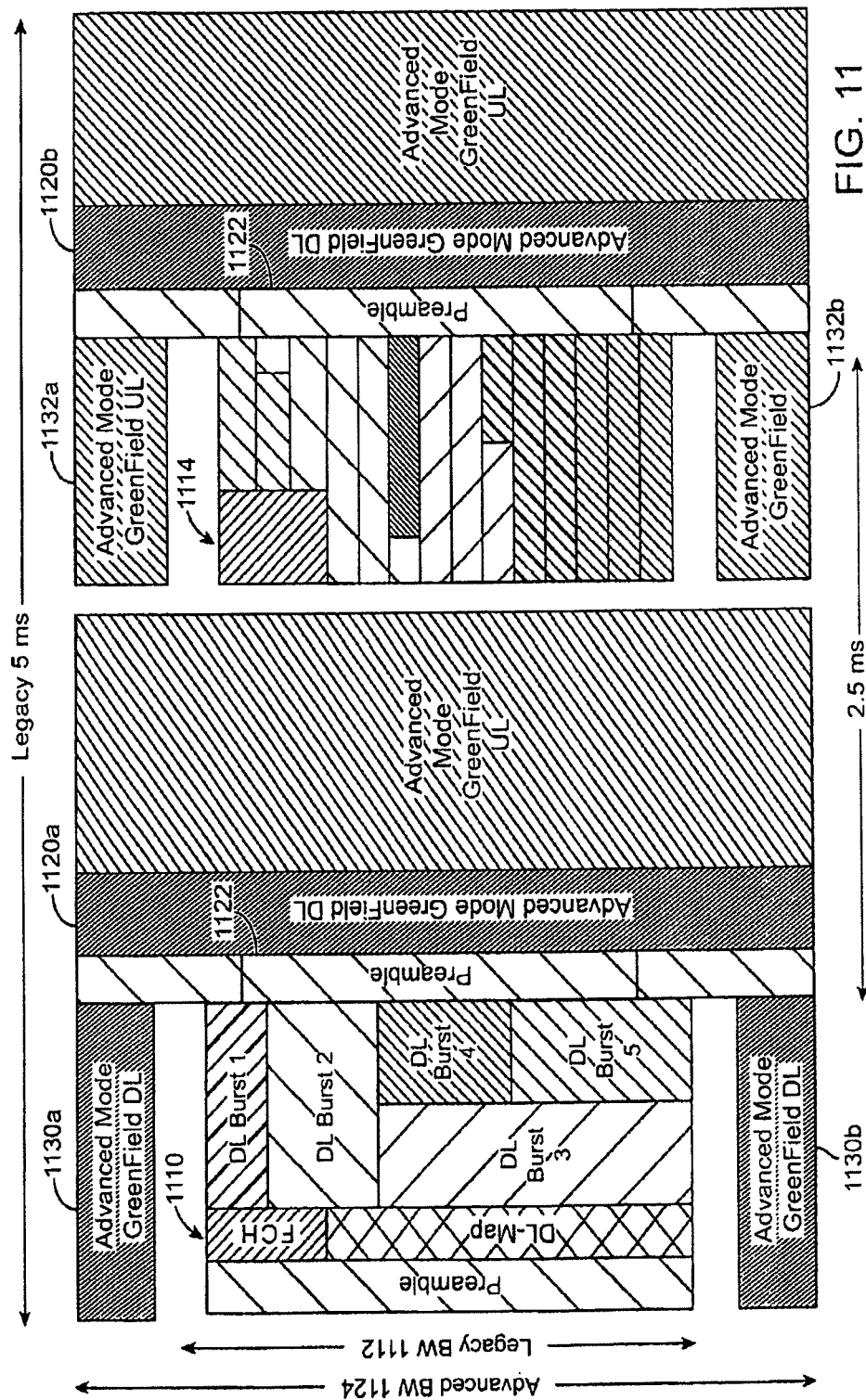


FIG. 10



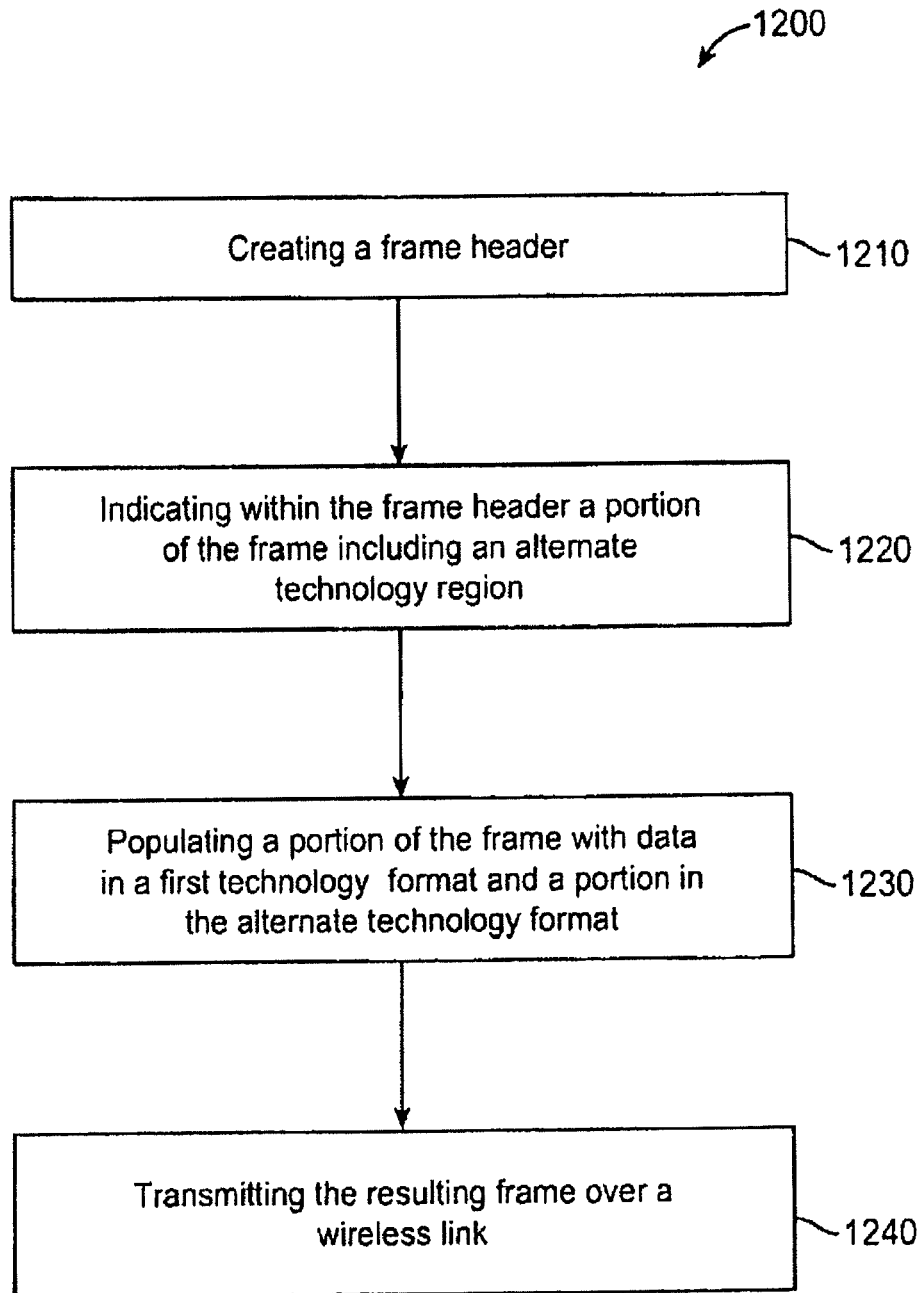


FIG. 12

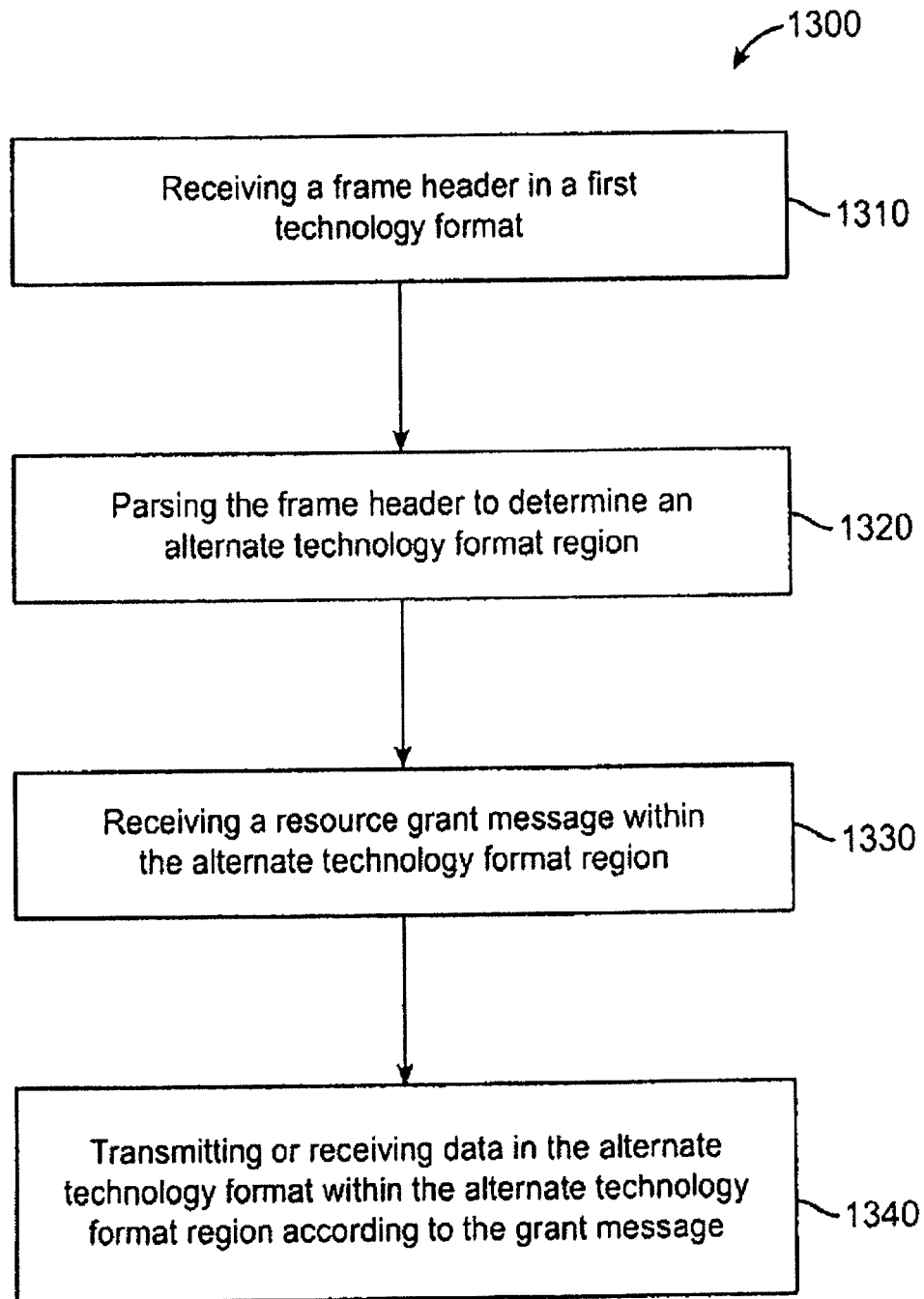


FIG. 13

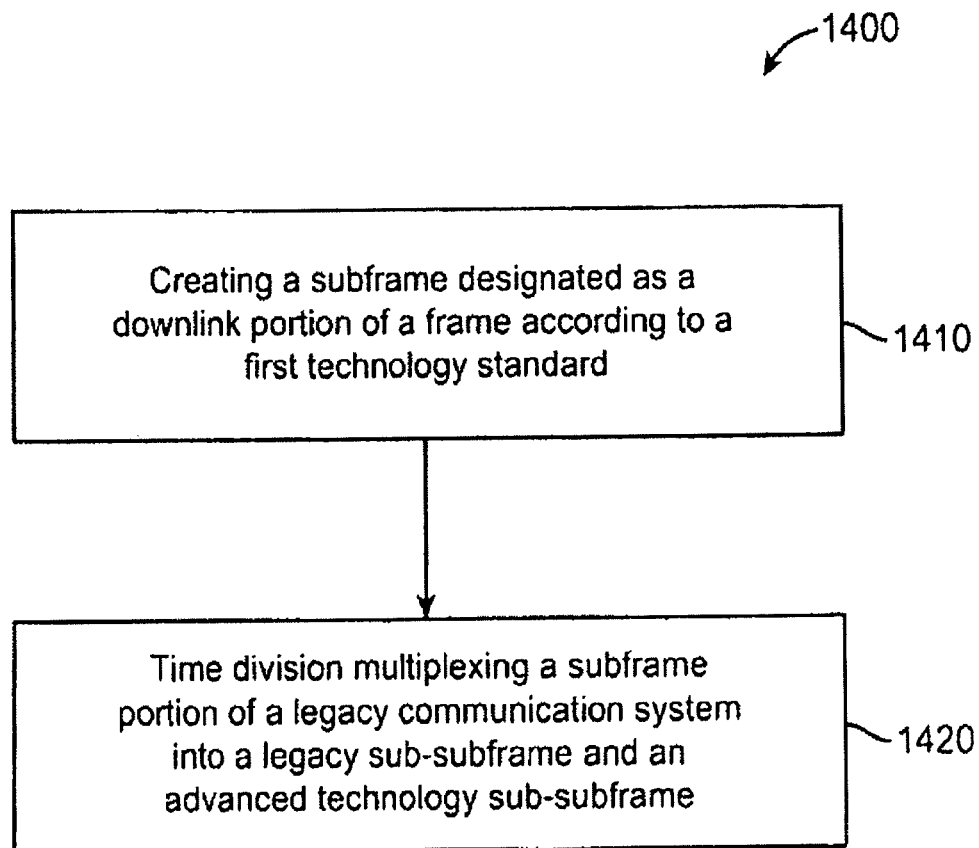


FIG. 14

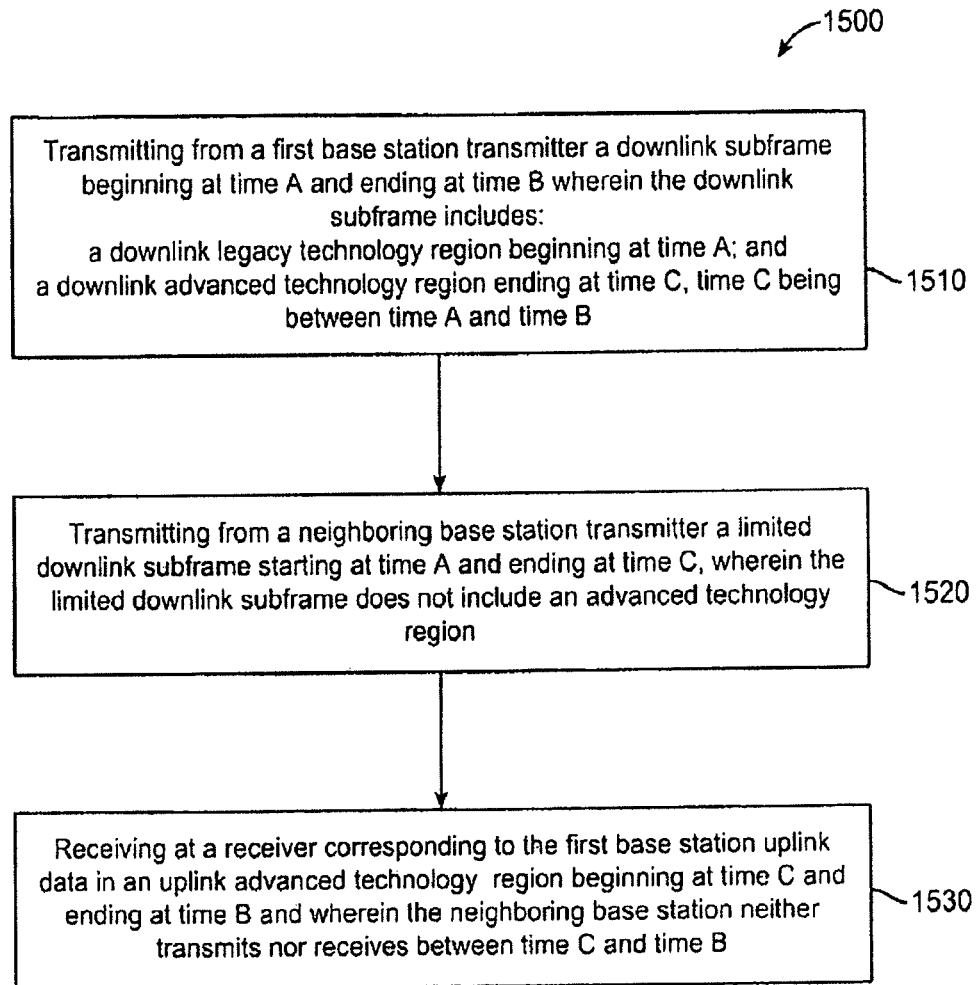


FIG. 15

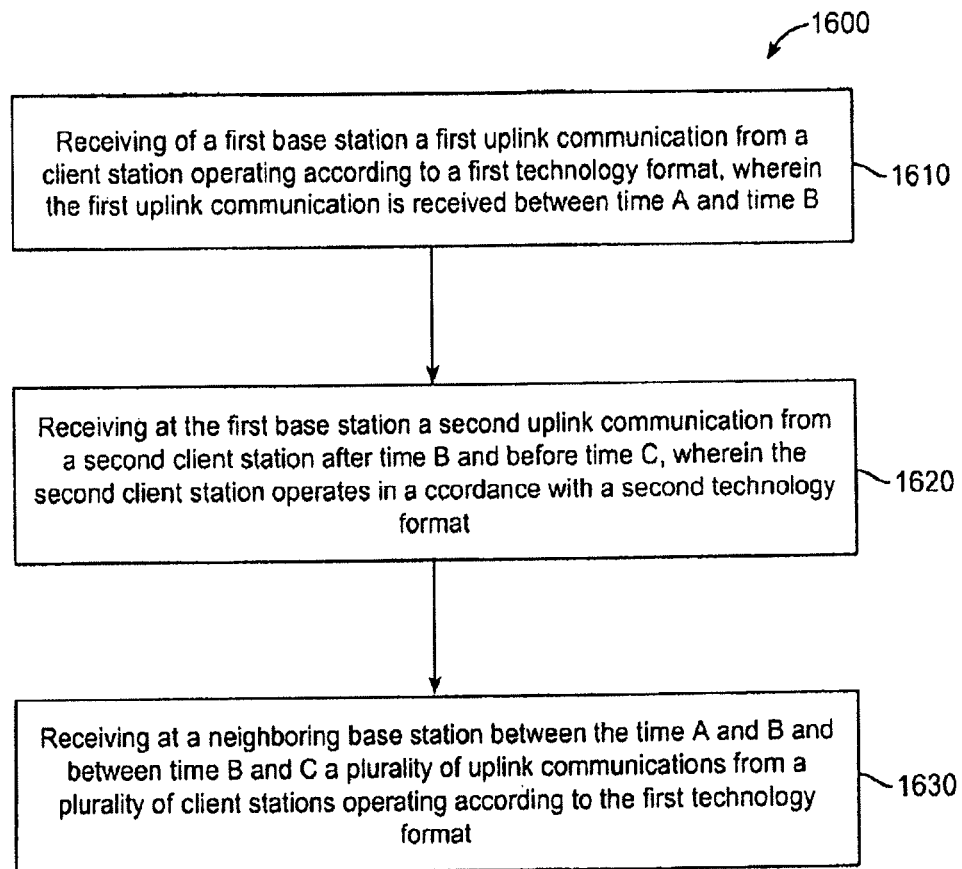


FIG. 16

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# ADVANCED TECHNOLOGY FRAME STRUCTURE WITH BACKWARD COMPATIBILITY

## CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 13/372,123, filed Feb. 13, 2012, which is continuation of U.S. patent application Ser. No. 12/265,435, filed Nov. 5, 2008, which issued as U.S. Pat. No. 8,139,537 on Mar. 20, 2012, which claims the benefit of U.S. Provisional Patent Application No. 60/986,257, filed Nov. 7, 2007, and U.S. Provisional Patent Application No. 61/030,183, filed Feb. 20, 2008. All of the above-referenced applications are incorporated by reference as if fully set forth herein.

## FIELD OF INVENTION

The present disclosure relates to the field of wireless communications. More particularly, the present disclosure relates to an advanced technology frame structure.

## BACKGROUND

It is a constant challenge for communication systems to integrate technological improvements in order to remain competitive with later developed communication systems implementing more advanced technology. The problem is even more apparent in wireless communication systems that have large investments in previously installed infrastructure.

A communication system risks becoming obsolete if it does not incorporate system improvements. However, the implementation of new technology into a communication system typically accommodates legacy devices. One way of supporting legacy devices is to develop a parallel infrastructure for supporting the new technology while slowly phasing out the legacy infrastructure. As can be imagined, supporting two independent systems is a costly approach to providing legacy support. Another approach is to implement updates that are backward compatible with legacy devices. However, often, the architecture of the legacy devices creates a bottleneck for system improvements.

There is a constant challenge to implement improvements into wireless communication systems, while maintaining support for legacy devices.

## SUMMARY

An advanced technology frame structure with backward compatibility and associated methods and systems are described herein. As a specific example, the frame structure, methods and systems herein described can be applied in a WiMax Orthogonal Frequency Division Multiple Access (OFDMA) communication system, although their use is not limited thereto. The advanced technology frame structure supports legacy devices with little or no change to and minimal effect on the legacy devices and enables the use of new physical layer and MAC layer enhancements that are not supported by the legacy system. In one demonstrative embodiment, the advanced technology frame structure can enhance the existing frame structure in dimensions of time, frequency, or a combination of time and frequency. In another demonstrative embodiment, the advanced technology frame structure time division multiplexes advanced technology subframes with the existing downlink and uplink

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subframes. For example, the existing downlink subframe can be divided into a legacy downlink subframe and an advanced technology downlink subframe. Similarly, the existing uplink subframe can be divided into a legacy uplink subframe and an advanced technology uplink subframe.

Demonstrative embodiments of the disclosure include a first base station transmitter/receiver communicating a downlink subframe. The downlink subframe starts at a first time and ends at a second time. The downlink subframe includes a downlink legacy technology sub-subframe, a downlink advanced technology sub-subframe (ending at a third time) and an uplink advanced technology sub-subframe (beginning approximately at the third time and ending on or before the second time.) A neighboring base station transmitter transmits a limited second downlink subframe, starting at the first time and ending before or at the third time. The limited second downlink subframe includes only a legacy downlink technology sub-subframe. The neighboring base station refrains from transmitting or receiving at between the third time and the second time. In one demonstrative embodiment, the downlink legacy technology sub-subframe ends at approximately a fourth time and the downlink advanced technology sub-subframe begins at approximately the fourth time and the first base station transmitter/receiver adjusts the occurrence of the fourth time on a frame to frame basis. In one aspect the first base station transmitter/receiver further communicates an uplink subframe. The uplink subframe begins at approximately the second time and ends at a fifth time. The uplink subframe includes an second downlink advanced technology sub-subframe beginning at approximately the second time, as well as an uplink legacy technology sub-subframe and a second uplink advanced technology sub-subframe having a boundary therebetween at a sixth time, wherein the sixth time is between the second time and the fifth time. The neighboring base station transmitter/receiver may receive a limited uplink sub-subframe beginning at approximately the end of the second downlink advanced technology sub-subframe. The first base station transmitter/receiver may adjust the occurrence of the sixth time on a frame to frame basis.

Further demonstrative embodiments of the disclosure include a first base station receiving a first uplink communication from a client station operating according to a first technology format. The first uplink communication is received between a first time and a second time. The first base station also receives a second uplink communication from a second client station after the second time and before a third time. The second client station operates in accordance with a second technology format. A neighboring base station receives between the first time and the second time and between the second time and the third time. It receives a plurality of uplink communications from a plurality of client stations operating according to the first technology format.

Yet further demonstrative embodiments of the disclosure include a first base station transmitter that transmits a downlink subframe beginning at a first time and ending at a second time. The downlink subframe begins with a downlink legacy technology sub-subframe and ends with an uplink advanced technology sub-subframe. The uplink advanced technology sub-subframe begins at a third time. A neighboring base station receives a limited uplink subframe starting at the third time and ending at the second time. The neighboring base station may transmit over a limited downlink subframe beginning at approximately the second time.

Further demonstrative embodiments of the disclosure include a subframe portion of a legacy communication



system that time division multiplexes a legacy sub-subframe into an advanced technology sub-subframe. A portion of the subframe portion to allocate to supporting advanced technology communications is determined. The process of time division multiplexing the subframe portion may comprise dynamically allocating a duration of the legacy sub-subframe based on the portion of the subframe portion to allocate to supporting advanced technology communications. The process of time division multiplexing the subframe portion may comprise time division multiplexing a downlink subframe portion of the legacy communication system into a legacy downlink sub-subframe and an advanced technology downlink sub-subframe. It may also comprise time division multiplexing an uplink subframe portion of the legacy communication system into a legacy uplink sub-subframe and an advanced technology uplink sub-subframe. The duration of the downlink subframe portion may be fixed and a ratio of a duration of the legacy downlink sub-subframe to a duration of the advanced technology downlink sub-subframe may be dynamically variable. The process of time division multiplexing the subframe portion may comprise time division multiplexing a downlink subframe portion of the legacy communication system into a legacy downlink sub-subframe and a first advanced technology downlink sub-subframe and a first advanced technology uplink sub-subframe. It may also comprise time division multiplexing an uplink subframe portion of the legacy communication system into a legacy uplink sub-subframe and a second advanced technology downlink sub-subframe and a second advanced technology uplink sub-subframe. The second advanced technology downlink sub-subframe may occur prior to the legacy uplink sub-subframe.

Further demonstrative embodiments of the disclosure include the legacy downlink sub-subframe including an indication of an allocation within the first advanced technology downlink sub-subframe. In other demonstrative embodiments, the legacy downlink sub-subframe includes an indication of a downlink map within the first advanced technology downlink sub-subframe. In yet another demonstrative embodiment, the first advanced technology downlink sub-subframe includes a preamble. The second advanced technology downlink sub-subframe may occur at a beginning of the uplink subframe portion of the legacy communication system. A beginning of an advanced technology frame having the time division multiplexed subframe portion may be synchronized with a beginning of a legacy frame. The time division multiplexed sub-subframes may be expanded to cover additional frequency portions.

Further demonstrative embodiments of the disclosure include a base station that supports legacy communications and advanced technology communications. The base station has several elements. It has a scheduler configured to determine the resources to allocate to advanced technology communications. It has a multiplexer configured to time division multiplex a subframe portion of a legacy communication system into a legacy sub-subframe and an advanced technology sub-subframe based on a control from the scheduler. It has a legacy resource mapper configured to allocate legacy communications within the legacy sub-subframe. And, it has an advanced technology resource mapper configured to allocate advanced technology communications within the advanced technology sub-subframe. The scheduler may determine the resources allocated based on resource allocation requests for advanced technology communications, such as, for example, based on information received from a system controller. The multiplexer may time

division multiplex a downlink subframe portion distinct from an uplink subframe portion.

Further demonstrative embodiments of the disclosure include a client station that supports advanced technology communications. It has a receiver configured to receive a time division multiplexed subframe portion of a legacy communication system having a legacy sub-subframe and an advanced technology sub-subframe. It has a legacy map decoder configured to access a resource map from the legacy sub-subframe and determine a resource allocation for an advanced technology map. And it has an advanced technology map decoder configured to access the advanced technology map and determine an advanced technology resource allocation in the advanced technology sub-subframe.

Further demonstrative embodiments of the disclosure include a base station that creates a subframe designated as a downlink portion of a frame according to a first technology format. A base station inserts an uplink sub-subframe according to an alternate technology into the downlink subframe.

Further demonstrative embodiments of the disclosure include a client station that receives a frame header in a first technology format. It is parsed to determine an alternate technology format region. A resource grant message within the alternate technology format region is received. Alternate technology formatted data is either transmitted or received within the alternate technology format region according to the grant message.

Further demonstrative embodiments of the disclosure include a base station that creates a frame header for a frame. The frame header indicates a portion of the frame including an alternate technology region. The base station populates a first region of the frame with data in a first technology format. The base station populates the alternate technology region with data in an alternate technology format. The resulting frame is transmitted.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of embodiments of the disclosure will become more apparent from the detailed description set forth below when taken in conjunction with the drawings, in which like elements bear like reference numerals.

FIGS. 1a-b are simplified timing diagrams of a legacy frame structure and an embodiment of an advanced technology frame structure.

FIG. 2 is a simplified timing diagram of a detailed view of an embodiment of an advanced technology frame structure.

FIGS. 3a-b are simplified timing diagrams of embodiments of advanced technology frame structures.

FIG. 4 is a simplified timing diagram of time synchronization between embodiments of advanced technology frame structures.

FIG. 5 is a simplified timing diagram of time synchronization between embodiments of advanced technology frame structures.

FIGS. 6a-d are simplified timing diagrams of embodiments of an advanced technology frame structure as seen from different device perspectives.

FIGS. 7a-c are simplified timing diagrams of embodiments of an advanced technology frame structure having further expansion along the frequency dimension.

FIG. 8 is a simplified functional block diagram of a system implementing an advanced technology frame structure.

FIG. 9 is a simplified functional block diagram of an embodiment of a base station implementing an advanced technology frame structure.

FIG. 10 is a simplified functional block diagram of an embodiment of a client station supporting advanced technology frame structure.

FIG. 11 is a flow chart illustrating an advanced technology frame structure incorporating several features.

FIG. 12 is a flow chart illustrating a process for creating an integrated, backwards compatible advanced technology frame structure.

FIG. 13 is a flow chart illustrating a process for receiving an integrated, backwards compatible advanced frame structure at a client station.

FIG. 14 is a flow chart illustrating a process for creating an integrated, backwards compatible advanced frame structure for transmission over a wireless link.

FIG. 15 is a flow chart illustrating a process for using a system that includes both advanced mode enabled base station transmitters and legacy only base station transmitters.

FIG. 16 is a flow chart illustrating a process for using a system that includes both advanced mode enabled base stations and legacy only base stations.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An advanced technology frame structure with backward compatibility, methods for implementing the advanced technology frame structure, and apparatus for implementing and communicating using the advanced technology frame structure are described herein. The advanced technology frame structure supports legacy communications as well as advanced technology communications by time division multiplexing a legacy frame structure such that minimal or reasonable changes are required for supporting both communications.

The frame structure and apparatus described herein use improvements to legacy IEEE 802.16e Orthogonal Frequency Division Multiple Access (OFDMA) time division duplex (TDD) frame structure as an example. However, the method and embodiments described herein are not generally limited to application in an OFDMA system, nor are they limited to application in a TDD system. In the timing diagrams, the frame structure includes a time dimension and a frequency dimension. The time dimension is illustrated on the horizontal axis and the frequency dimension is illustrated on the vertical axis. The principles describe herein can be applied to other system such as other IEEE 802.16-type systems, WiBro, Wi-Fi, Long Term Evolution (LTE) and proprietary systems. In one aspect, the advanced technology frame structure supports legacy devices with little or no change to and minimal effect on the legacy devices and enables the use of new physical layer and MAC layer enhancements that are not supported by the legacy system.

In the description that follows, we often refer to a legacy and advanced technology backwards compatible frame. However, in general, the techniques described herein can be used to provide combined operation of a first technology format and one or more additional technology formats. The "legacy" system need not have been developed or deployed before the "advanced" system.

The first and second technology formats may typically have some features in common. They may differ by employing different overhead messaging, physically layer techniques, encoding techniques, access techniques, power con-

trol, physical (PHY) layer parameters, media access (MAC) layer parameters and the like.

FIGS. 1a and 1b are simplified timing diagrams of a legacy frame structure 102 and an embodiment of an integrated advanced technology frame structure with backwards compatibility 110. The legacy frame structure 102 is configured as a TDD frame having a legacy downlink subframe portion 104 followed by a legacy uplink subframe portion 106. The duration of the legacy frame 102 is fixed, although the duration of each subframe portion 104, 106 may vary across distinct frames. That is, each of the subframe portions 104, 106 may occupy varied percentages of the entire frame duration across distinct frames, but the sum of the downlink subframe duration and the uplink subframe duration is constant. In some systems, the ratio of the subframe portions is set on a system wide basis.

An embodiment of an advanced technology frame structure 110 that is backward compatible with the legacy frame structure 102 is shown in FIG. 1b. For the purposes of discussion, the downlink subframe 112 and uplink subframe 114 in the advanced technology frame are shown as having the same duration as the downlink subframe 104 and uplink subframe 106 in the legacy frame, although other variations can be implemented in operation.

As shown in FIG. 1b, the advanced technology frame 110 fully supports the legacy communications by retaining the legacy downlink sub-subframe portion 116 in its downlink subframe 112 and the legacy uplink sub-subframe portion 130 in its uplink subframe 114. Specifically, in the advanced technology frame 110, the legacy downlink subframe portion 112 is time division multiplexed into a legacy downlink sub-subframe 116 and an advanced technology downlink sub-subframe 118. Similarly, the legacy uplink subframe portion 114 is time division multiplexed into a legacy uplink sub-subframe 130 and an advanced technology uplink sub-subframe 132.

The portion of each sub-subframe that is allocated to legacy communications or advanced technology communications can be fixed or variable. In one embodiment, the ratio of a duration of the legacy downlink sub-subframe to a duration of the advanced technology downlink sub-subframe is dynamically variable, and can be based on, for example, resource allocation requests for each type of communications, predetermined ratios, client station capabilities, ratios of client station capabilities, and the like or some combination thereof. Similarly, the ratio between the duration of the legacy uplink sub-subframe and the duration of the advanced technology uplink sub-subframe is dynamically variable based upon one or more factors as enumerated above. Additionally, the respective ratios of legacy to advanced technology durations can be different in the downlink and uplink subframe portions.

The legacy downlink sub-subframe 116 includes a header 120. Typically, the header 120 includes a preamble 122 which is used by the client station to acquire both time and frequency synchronization among other information. In the embodiment shown in FIG. 1b, the header 120 indicates to the advanced mode client stations the location of an advanced technology resource map etc. 124 within the advanced mode downlink subframe 118. Thus, in one embodiment, a client station operating in a system using the integrated advanced TDD frame structure 110 shown in FIG. 1b tracks the preamble 122 and retrieves information from the header 120 or other element of the legacy mode downlink sub-subframe 116 regarding the location of the advanced technology resource map etc. 124. The advanced mode map etc. 124 indicates resource allocations within the

advanced mode sub-subframe **118**. In addition, in one embodiment, the advanced technology resource map etc. **124** also indicates resource allocations within the advanced mode sub-subframe **132**.

As shown in FIG. 1, the downlink advanced technology sub-subframe **118** may include the advanced technology resource map etc. **124** that indicates the advanced technology downlink and uplink resource allocations granted to the advanced technology enabled devices. The location of the advanced technology resource map etc. **124** is indicated in a downlink legacy resource map or an extension of a legacy resource map. Thus, in one embodiment, a client station operating in a system using the integrated, backwards compatible advanced frame structure **110** as shown in FIG. 1 tracks the preamble **122** and retrieves information from the header **102** or other element of the legacy mode downlink sub-subframe as to the location of the advanced technology resource map etc. **124**.

FIG. 2 is a simplified timing diagram of a detailed view of an embodiment of an advanced technology frame structure **200** with backwards compatibility. In FIG. 2, the advanced technology resource map etc. **124** may be limited or omitted, and the advanced technology resource allocation information can be communicated in an extension of the legacy resource map. For example, a legacy downlink resource map **208** within the header **206** can include an extended identifier or code **210** that identifies an information element **220** that identifies the resources allocated to advanced technology communications, both uplink and downlink. In another example, a legacy downlink resource map **208** can include a downlink advanced-mode granting information element. The downlink advanced-mode granting information element can grant the downlink and uplink resource allocations in the advanced technology downlink sub-subframe **204** and advanced mode technology uplink sub-subframe **222**. The downlink advanced-mode pointer information element **210** and the uplink advanced-mode extended identifier or granting information element within the legacy uplink resource map **220** can be made to be backward compatible to the legacy resource maps by using extended codes or identifiers that have been reserved in the legacy system for expansion.

An advanced mode client station operating in a system using the backward-compatible advanced technology frame structure **200** acquires both time and frequency synchronization using the legacy preamble **212**. In the embodiment shown in FIG. 2, downlink map information element **210** within the header **206** indicates to the advanced mode client stations the location of allocations within the advanced mode downlink and uplink sub-subframes **204** and **222**. Thus, in one embodiment, a client station operating in a system using the backwards compatible advanced frame structure **200** as shown in FIG. 2 tracks the preamble **212** and retrieves information from the header **206** or other element of the legacy mode downlink sub-subframe **202**, such as downlink burst **214**, regarding uplink and downlink allocations within the advanced mode downlink and uplink sub-subframes **204** and **222**.

FIGS. 3a and 3b are simplified timing diagrams of embodiments of advanced technology frame structures **302** and **304**. FIG. 3a illustrates the advanced technology frame structure **302** similar to the one described in FIG. 1b. FIG. 3b illustrates an alternative advanced technology frame structure **304** supporting low latency communications for client stations operating in the advanced mode.

In the low latency advanced technology frame structure **304** as shown in FIG. 3b, a frame of 5 ms length, for

example, is divided into first and second subframes **310** and **312** of fixed duration (e.g., 2.5 ms each subframe). Each of the first and second subframes **310** and **312** is time division multiplexed into a legacy sub-subframe **320**, **330** and at least one advanced technology downlink sub-subframe **322**, **332** and at least one uplink sub-subframe **324**, **334**, respectfully. As shown in FIG. 3b, the first subframe **310** comprises the legacy downlink sub-subframe **320**, as well as both an advanced technology downlink sub-subframe **322** and advanced technology uplink sub-subframe **324**, while the second subframe **312** comprises the legacy uplink subframe **330**, as well as at least one advanced technology downlink sub-subframe **332** and advanced technology uplink sub-subframe **334**. As shown, each subframe portion includes an advanced technology uplink sub-subframe and an advanced technology downlink sub-subframe.

The first subframe **310** is configured with a different time division multiplex ordering than the second subframe **312**. As such, the advanced mode downlink sub-subframe **332** can be configured to begin at a fixed offset from the beginning of the legacy sub-subframe **320**. In one embodiment, the fixed offset is configured such that a downlink sub-subframes occurs periodically, such as at 2.5 ms intervals as shown in the exemplary embodiment of FIG. 3b. In such a configuration, from the perspective of an advanced mode client station, the downlink subframes occurs periodically at a 2.5 ms offsets, or more generally, at twice the rate of the backward-compatible advanced mode frame structure **302**. In such a configuration, the sub-subframe boundary within the subframes **310** and **312** can remain configurable, such as, for example, to adapt to current loading etc.

As such, the legacy frame is divided in such a way that it supports two advanced technology DL/UL pairs for each legacy DL/UL pair. As compared with the frame structure in FIG. 3a, the low latency advanced technology frame structure in FIG. 3b provides for a shorter cycle time between the downlink and uplink, thereby lowering latency. In order to further reduce the latency, the legacy frame can be divided in such a way that it supports three or more DL/UL pairs for each legacy DL/UL pair.

Low latency is achieved by reducing the time lag between successive advanced mode downlink (or uplink) sub-subframes. For example, note that in FIG. 3a a downlink transmission that enters the transmission queue just after the advanced mode map is generated may remain queued at least until the next downlink subframe. As such a downlink transmission may remain queued about 5 milliseconds (msec or ms), even when the system has ample capacity to service the transmission.

In comparison, note that in FIG. 3b, an advanced mode downlink transmission that enters the transmission queue just after the advanced mode map is generated has a much shorter maximum wait time because advanced mode downlink sub-subframes occur every 2.5 msec on average. The average latency can be yet further reduced by increasing the number of downlink sub-subframes that occur within any legacy subframe. These same principles apply directly to uplink advanced mode transmissions.

FIG. 4 is a simplified timing diagram of time synchronization between embodiments of advanced technology frame structures. The upper timing diagram illustrates the advanced technology frame structure with low latency. The lower timing diagram illustrates an example of a legacy frame structure synchronized to the advanced technology frame structure. The legacy frame can be, for example, a frame generated by a neighboring base station lacking the capability to support advanced technology communication.

These co-existence techniques can be critical when dual mode base stations operate in close proximity to single mode base stations.

As shown in FIG. 4, the beginning of the low latency, backwards compatible advanced technology frame **304** transmitted by a first base station is time synchronized with the beginning of a compatible legacy frame **400** transmitted by a second, neighboring base station. Alternatively, advanced technology frame **304** and the legacy frame **400** may be transmitted by a common base station but on different frequency bands/channels. The first base station transmitter and second base station transmitter neighbor one another when the coverage area corresponding to each base station is within a localized geographical region or when the two transmitters are substantially co-located and operating in different frequency bands/channels. The legacy frame refrains from having resources allocated during the first advanced technology uplink sub-subframe and the second advanced technology downlink sub-subframe in order to mitigate the deleterious effects of collisions between uplink and downlink transmissions.

Transmission or receptions within the various subframes may terminate at or before the end of the corresponding subframe. During periods of heavy traffic, communications may occur throughout an entire subframe. If the system is not fully loaded, communications may not occur over some portion of a subframe.

The duration over which communications are conducted within the limited subframes **410** and **412** is reduced to a limited downlink sub-subframe **402** and a limited uplink sub-subframe **404** respectively. As shown in FIG. 4, the beginning of the subframe **310** and the beginning of the limited legacy downlink subframe **410** are synchronized to time A. The sub-subframe **402** ends at time B, coinciding approximately with the beginning of the uplink advanced mode sub-subframe **324**. Likewise the sub-subframe **322** ends at time B. The end of uplink advanced mode sub-subframe **324** coincides with the end of the downlink subframes **310** and **410** at time H.

In a similar manner, the downlink advanced mode sub-subframe **332** begins at the beginning of the uplink subframes **312** and **412**, at time H. The downlink advanced mode sub-subframe **332** ends at time C. The sub-subframe **404** and the sub-subframe **330** are synchronized to begin at time C. The sub-subframe **404**, the subframe **412**, the subframe **312** and the sub-subframe **334** terminate at time D or earlier.

In some embodiments, the occurrence of time B and time C is configurable, typically as a system wide parameter. The ordering of the uplink legacy sub-subframe **330** and uplink advanced mode sub-subframe **334** can be reversed. The time at which the downlink legacy sub-subframe **320** ends and the downlink advanced mode sub-subframe **322** begins, indicated as time J on FIG. 4, can be configurable and may change from frame to frame and from base station to base station. For example, if the time J is configurable on a frame to frame basis, it may be changed periodically, such as every second, every frame, based on loading or the like. Likewise the time at which the uplink legacy sub-subframe **330** ends and the uplink advanced mode sub-subframe **334** begins, indicated as time I on FIG. 4, can be configurable and may change from frame to frame and from base station to base station.

FIG. 5 is a simplified timing diagram of alternative time synchronization between embodiments of advanced technology frame structures. In the embodiment of FIG. 5, the timing of the advanced technology frame is offset from the

frame timing for the legacy frame **500** by some fixed amount. The limited uplink subframe **510** includes a limited sub-subframe **504** that is synchronized to occur during the advanced technology uplink sub-subframe **334** within the downlink subframe **310**. The limited legacy downlink subframe **512** includes a limited sub-subframe **502** that is synchronized to occur during the downlink advanced technology sub-subframe **332** within the uplink subframe **312**. In some systems, the configuration shown in FIG. 5 may be advantageously applied as the ratio of resources dedicated to the advanced mode operation increases. Note that in typical systems, the uplink sub-subframe **504** corresponds to the frame before the frame that includes the downlink sub-subframe **502**.

Thus, the beginning of the sub-subframe **332** and the beginning of the legacy downlink sub-subframe **502** are synchronized to begin a time F. The legacy downlink transmissions in the sub-subframe **504** are terminated at time G or earlier. Likewise transmission in the sub-subframe **332** are terminated at time G or earlier. In a similar manner, the legacy uplink sub-subframe **504** and the sub-subframe **334** are synchronized to begin a time E. The legacy uplink transmissions in the sub-subframe **504** are terminated at time F or earlier. Likewise, the advanced mode uplink transmissions in the sub-subframe **334** are terminated at time F or earlier.

FIGS. 6a-d are simplified timing diagrams of alternative embodiments of an advanced technology frame structure as seen from different device perspectives. FIGS. 6a-6d do not specify or otherwise label the advanced technology sub-subframes as supporting downlink or uplink communications. Although FIGS. 1-5 illustrate specific examples of advanced uplink and advanced downlink configurations, the advanced technology region is not limited to any particular configuration, and the advanced technology region can be divided into virtually any number of uplink and downlink sub-subframes and such advanced sub-subframes may occur in any order. For example, as shown in FIG. 2, the advanced technology downlink region can occupy substantially all of the advanced technology sub-subframe immediately following the legacy downlink sub-subframe. Alternatively, as illustrated in FIG. 3b, the advanced technology sub-subframe can be divided into a downlink/uplink pair, triple etc. Other configurations can be, of course, implemented to be tailored to specific communication needs in a system.

Typically, when the advanced mode technology is initially deployed, legacy usage greatly exceeds advanced technology usage. As time moves forward, legacy usage decreases and is eventually phased out. According to the embodiments shown in FIGS. 1b and 2, even after the usage of the legacy technology is fully phased out, the advanced mode operation continues to use one or more elements of the legacy header and, thus, these legacy elements continue to be transmitted even after use of the legacy system has been phased out.

For example, according to the embodiment shown in FIG. 2, a client station operating in advanced technology mode uses both the legacy preamble as well as information embedded in the legacy downlink map and legacy uplink map. In the embodiment shown in FIG. 1b, although a client station operating according to the advanced mode technology does not use the legacy header to acquire mapping etc. information, it uses the legacy header for some elements, such as the preamble. Thus, according to the embodiment shown in FIGS. 1b and 2, elements of the legacy header are used in the advanced technology mode operation even after legacy operation has been phased out.

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FIG. 6a illustrates an alternative advanced technology frame structure in which the advanced technology frame is decoupled from the legacy technology frame. The advanced technology enabled base station is able to support communications with client stations that are configured to receive either the legacy frames or the advanced technology frames or both. Since both the legacy and the advanced technology portions in the frames are multiplexed to the air link in a time division manner, the advanced technology enabled base stations can allocate or process data in resource allocations in each of the sub-subframes to support communications with all client stations.

The backward-compatible advanced technology mode frame structure 600 includes a legacy downlink subframe 602. However in contrast to operations such as shown in FIGS. 1-5, the advanced mode client stations need not monitor or any portion of the legacy downlink subframe 602, as clearly illustrated below in FIG. 6c. The frame structure 600 also includes two advanced mode fields 604 and 610. As shown earlier with respect to FIG. 3b, the fields 604 and 610 may include one or more advanced technology uplink or downlink sub-subframe (not shown.)

In the embodiment shown in FIG. 6a, the advanced mode field 604 includes a stand-alone advanced mode header 620. In this way, advanced mode operation may be independent of the legacy operation. As such, a custom header tailored for the needs of the advanced mode operation may be developed and legacy header usage can be eliminated when legacy operation is phased out.

FIG. 6b illustrates a legacy client station perspective of an advanced technology frame structure embodiment, such as the embodiment illustrated in FIG. 6a. As illustrated in FIG. 6b, the legacy client station does not communicate over the advanced technology sub-subframes, and likely has no awareness of the advanced technology sub-subframes. From the perspective of the legacy client station, the advanced technology sub-subframes appear as regions within which the client station is not allocated any resources.

FIG. 6c illustrates an advanced technology enabled client station perspective of an advanced technology frame embodiment, such as the embodiment illustrated in FIG. 6a. As shown in FIG. 6c, the advanced technology enabled client station makes no communications over the legacy subframes, assuming that the advanced technology enabled client station does not support legacy communications. Such operation as possible because of the inclusion of the stand-alone advanced mode header 620. In contrast, according to the embodiment shown in FIGS. 1-5, the advanced mode client station monitors a portion of the subframe 602 in order to obtain certain information included in the legacy frame.

As described earlier, the time division multiplex operation does not need to allocate fixed amounts of time to support either the legacy communications or advanced technology communications. Thus, the amount of resources dedicated to supporting each type of communication may dynamically vary based on the load placed on each type of communications.

There may be few advanced technology enabled client stations at the initial rollout of the advanced technology system, and thus minimal resources and sub-subframe duration may be allocated to supporting the advanced technology communications. Over time, more advanced technology enabled client stations will begin to use the system. At some point in time, virtually no legacy client stations will exist, and the frame structure supports the ability to allocate minimal resources and sub-subframe duration to supporting the legacy communication.

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FIG. 6d illustrates the advanced technology frame at a time in which support for legacy communications has substantially been eliminated. The entire downlink and uplink subframes may be dedicated to supporting advanced technology communications. In contrast, in the embodiments shown in FIGS. 2 and 3b, some elements of the legacy subframe continue to be used in advanced mode operation even after all legacy devices have been phased out of the system.

In some systems, when the advanced technology system is first deployed and the ratio of legacy to advanced mode usage is quite high, it is efficient for advanced mode operation to use certain overhead information carried in the legacy mode sub-subframe. By using overhead information carried in the legacy mode sub-subframe, the advanced mode sub-subframe need not carry such information and can be more fully dedicated to carrying advanced mode data.

However, sometimes the legacy frame overhead is not optimal for use in advanced mode operation. For example, it may be advantageous to use an improved preamble or a new map format for advanced operation. To the extent that the advanced mode operation relies on elements of the legacy sub-subframe, the ability to incorporate differences between legacy and advanced mode operation is limited. Thus, in some implementations, the embodiments shown in FIGS. 1-5 are advantageous at initial deployment while the embodiment shown in FIG. 6 may have long-term advantages. As such, a system may be designed which transforms over time from an implementation consistent with FIGS. 1-5 to an implementation consistent with FIG. 6.

FIGS. 7a-c are simplified timing diagrams of embodiments of an advanced technology frame structure with legacy compatibility operating in a further expanded frequency dimension. As previously illustrated, the advanced technology frame structures can be implemented by a system that operates and occupies the same bandwidth as a legacy communication system. However, the frame structure is not limited to maintaining the same frequency bandwidth in the advanced technology system, as will be described below.

FIG. 7a illustrates, from the perspective of an advanced technology enabled base station, an advanced technology frame structure that supports legacy communications with additional operating bandwidth as compared with the legacy system. The advanced technology frame structure maintains the time division multiplexing of the legacy sub-subframes and the advanced technology sub-subframes. However, the advanced technology frame also supports communications in expanded frequency dimensions, incorporating a frequency division multiplexing component. The following examples illustrate frequency expansion both above and below the frequency bands allocated to the legacy communication system, but the advanced technology frame structure can readily be applied to one sided frequency expansion as well.

As shown in the timing diagram of FIG. 7a, each of the subframe portions has a frequency portion supporting advanced technology communications. The additional frequency portion can be, for example, additional subcarriers of an OFDMA symbol. There can be one or more predetermined guard bands isolating the legacy frequency bands from the appended frequency portions, but these guard bands may be eliminated or otherwise omitted in those subframe portions that support advanced technology communications.

As shown in FIG. 7a, an advanced technology enabled base station can configure both the advanced technology

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portions and the legacy portions of the frame structure. Although the advanced technology portions not appended to a legacy sub-subframe may be configured to carry either downlink or uplink communications, those advanced technology frequency bands that are appended to the legacy sub-subframes typically are configured to support the same communication direction as supported by the associated legacy sub-subframe. For example, the advanced technology frequency bands appended to the downlink sub-subframe will be configured for downlink communications, while the advanced technology frequency bands appended to the uplink sub-subframe will be configured for uplink communications.

FIG. 7b illustrates the wide band advanced technology frame structure from the perspective of a legacy client station. The legacy device has no awareness of the advanced technology regions or is not allocated resources within any of the advanced technology sub-subframes or frequency regions from the perspective of the legacy device the advanced technology.

FIG. 7c illustrates the wide band advanced technology frame structure from the perspective of a wideband advanced technology enabled client station. In the embodiment of FIG. 7c, the advanced technology client station is assumed to not support legacy communications.

From the perspective of the wideband advanced technology enabled client station, the frame structure supports advanced technology communications, with minor limitations on uplink and downlink transmissions in the sub-subframe portions that overlap the legacy sub-subframes. These limitations diminish as the resources allocated to legacy devices shrinks.

FIG. 8 is a simplified functional block diagram of a system 800 implementing an advanced technology frame structure. The wireless communication system 800 includes a plurality of base stations, 810-1 and 810-2, coupled to a network 814, such as a wide area network. Each base station, e.g., 810-1, services devices within its respective coverage area, e.g., 812-1, sometimes referred to as a cell.

A first base station 810-1 serves a first coverage area 812-1 and a second base station 810-2 serves a corresponding second coverage area 812-2. The base stations 810-1 and 810-2 are depicted as adjacent or otherwise neighboring base stations for the purposes of discussion. In one embodiment, the base station 810-1 comprises two base station transmitters configured to transmit on different frequency channels/bandwidths.

As an example, the base stations 810-1 and 810-2 serve those devices within the respective coverage areas 812-1 and 812-2. As shown in FIG. 8, first and second client stations or client stations 820a and 820b are within the first coverage area 812-1 and can be supported by the first base station 810-1.

For the purposes of discussion, the first base station 810-1 can support advanced technology communications as well as legacy communications. The second base station 810-2 can be limited to supporting legacy communications. Similarly, assume for the purposes of discussion that the first client station 820a is advanced technology enabled, while the second client station 820b is a legacy device, incapable of advanced technology communication.

The first base station 810-1 can support communications with both the first and second subscribe stations 820a and 820b by implementing an advanced technology frame structure such as one illustrated in FIGS. 1-7. The first base station 810-1 can allocate legacy resources to the second client station 820b in the legacy sub-subframes and can

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allocate advanced technology resources to the first client station 820a in the advanced technology sub-subframes. As discussed earlier, the advanced technology sub-subframes are time division multiplexed with the legacy sub-subframes in the duration of a legacy subframe portion.

The advanced technology frame timing implemented by the first base station 810-1 can be synchronized to the frame timing of the legacy second base station 810-2, such as exemplified in FIG. 4, to minimize the collisions that may occur if the advanced uplink sub-subframes occur during the legacy downlink subframes, or if advanced downlink sub-subframes occur during the legacy uplink subframes.

FIG. 9 is a simplified functional block diagram of an embodiment of a base station 810 implementing an advanced technology frame structure. The base station 810 includes both transmission and reception capabilities and is some times referred to as a base station transmitter/receiver.

The base station 810 can be, for example, the first base station 810-1 shown in the wireless communication system of FIG. 8. The base station 810 includes the capabilities to configure and support one or more advanced technology sub-subframes in each legacy subframe. The base station 810 functionality is simplified to include those portions that operate as part of advanced technology support. Other portions of the base station 810 are omitted for the purposes of brevity and clarity.

The base station 810 includes an antenna 902 coupled to an output of a transmitter 960 as well as to an input of a receiver 910. The output of the receiver 910 can be coupled to an input of a Uplink Message Processor 920 that can be configured, for example, to process uplink resource allocation requests from legacy and advanced technology client stations. The uplink message processor 920 can inform a scheduler 970 of the requests.

The scheduler 970 can be configured to determine the resources to allocate to legacy communications as well as advanced technology communications. The scheduler 970 can be configured to control the duration of the time division multiplexing of the legacy subframes as well as any frequency multiplexing employed. In one embodiment, these values are dynamically varied, and each base station can be configured to independently determine them. In another embodiment, the scheduler 970 determines the resources to allocate based on one or more settings received from a system controller (not shown, but which may be an element of the network 814.) These settings may influence the time division multiplex timing as well as any frequency multiplexing.

The scheduler 970 can be configured to control a multiplexer 974 that is configured to time division multiplex a subframe portion of a legacy communication system into a legacy sub-subframe and an advanced technology sub-subframe based on a control from the scheduler 970.

The scheduler 970 can also control a legacy resource mapper 942 as well as an advanced resource mapper 944. Each of the legacy resource mapper 942 and advanced resource mapper 944 can be configured to selectively receive data from a data source 930 and map it to an appropriate sub-subframe. The scheduler 970 can control or otherwise enable the selection of the data by the active resource mapper.

The legacy resource mapper 942 is configured to allocate legacy communications to the legacy sub-subframe and the advanced technology resource mapper 944 is configured to allocate advanced technology communications to the advanced technology sub-subframe.

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The output of the legacy resource mapper **942** is coupled to a legacy downlink signal processor **952** that configures the legacy downlink sub-subframe using the data mapped by the legacy resource mapper **942**. Similarly, the output of the advanced resource mapper **944** is coupled to an advanced downlink signal processor **954** that configures the advanced technology downlink sub-subframe using the data mapped by the advance resource mapper **944**.

The outputs of the legacy downlink signal processor **952** and advanced downlink signal processor **954** are each coupled to respective inputs of the multiplexer **974**. The active multiplexer path, as determined by the scheduler **970**, is coupled to the transmitter **960** for downlink transmission over antenna **902**.

Typically, the various elements shown in FIG. **9** are controlled by a processor **972** which is capable of directing the functioning of one or more of the elements shown in FIG. **9**. (Connections Between the Various Elements are not Shown so as not to Complicate the Diagram.) Typically the operation of the processor **972** is accomplished with reference to one or more storage media, such as a memory **974**. The functionality of all or portions of one or more of the elements shown can be implemented as one or more computer readable instructions encoded on one or more storage media.

FIG. **10** is a simplified functional block diagram of an embodiment of a client station **820** supporting advanced technology frame structure. The client station **820** can be, for example, an advanced technology enabled client station, e.g., **820a**, in the wireless communication system of FIG. **8**.

The client station **820** includes a receiver configured to receive a time division multiplexed subframe portion of a legacy communication system having a legacy sub-subframe and an advanced technology sub-subframe.

The client station **820** includes an antenna **1006** through which the uplink and downlink signals are communicated. The antenna **1006** couples the downlink signals to a transmit/receive (T/R) switch **1010**. The T/R switch **1010** operates to couple the downlink signals to the receiver of the client station **820** during a downlink subframe and operates to couple uplink signals from the transmitter portion of the client station **120** during an uplink subframe.

During the downlink portion or subframe, the T/R switch **1010** couples the downlink signals to a receive RF front end **1020**. The receive RF front end **1020** can be configured, for example, to amplify, frequency convert a desired baseband frequency, and filter the signal. The baseband signal is coupled to a receive input of a baseband processor **1040**.

The receive input of the baseband processor **1040** couples the received baseband signal to an Analog to Digital Converter (ADC) **1052** that converts the analog signal to a digital representation. The output of the ADC **1052** is typically filtered, such as by filter **1053**, the output of which can be coupled to a transformation module, such as Fast Fourier Transform (FFT) engine **1054** that operates to convert the received time domain samples of an OFDM symbol to a corresponding frequency domain representation. The sample period and integration time of the FFT engine **1054** can be configured, for example, based upon the downlink frequency bandwidth, symbol rate, subcarrier spacing, as well as the number of subcarriers distributed across the downlink band, or some other parameter or combination of parameters.

The output of the FFT engine **1054** can be coupled to a channelizer **1056** that can be configured to extract the subcarriers from those symbols that are allocated to the particular client station **120**. The channelizer **1056** can be

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configured, for example, to extract the portion of the legacy or advanced downlink sub-subframes relevant to the client station **120**. The output of the channelizer **1056** can be coupled to a destination module **1058**. The destination module **1058** represents an internal destination or output port to which received data may be routed.

The client station **120** also includes a legacy map decoder **1070** configured to access a resource map from the legacy sub-subframe and determine a resource allocation for legacy technology map and an advanced technology map decoder **1080** configured to access the advanced technology map and determine an advanced technology resource allocation in the advanced technology sub-subframe. The legacy map decoder **1070** and the advanced technology map decoder **1080** can be coupled to the channelizer **1056** to control the extraction of the data in the allocated downlink resources. Similarly, the legacy map decoder **1070** and the advanced technology map decoder **1080** can be coupled to the uplink channelizer **1064** to control the allocation of uplink data to the appropriate allocated uplink resources.

The uplink path is complementary to the downlink signal path. A source module **1062** of the base band processor **1040**, which may represent an internal data source or an input port, generates or otherwise couples uplink data to the baseband processor **1040**. The source **1062** couples the uplink data to an uplink channelizer **1064** that operates to couple the uplink data to appropriate uplink resources that are allocated to support the uplink transmission.

The output of the uplink channelizer **1064** is coupled to an FFT engine **1066** that operates to transform the received frequency domain subcarriers to a corresponding time domain OFDM symbol. The uplink FFT engine **1066** may support the same bandwidth and number of subcarriers as supported by the downlink FFT engine **1054**.

The output of the uplink FFT engine **1066** is coupled to a Digital to Analog Converter (DAC) **1068** that converts the digital signal to an analog representation. The analog baseband signal is coupled to a transmit front end **1022**, where the signal is frequency translated to the desired frequency in the uplink band. The output of the transmit front end **1022** is coupled to the T/R switch **1010** that operates to couple the uplink signal to the antenna **1006** during the uplink subframe.

A local oscillator (LO) **1030** is coupled to a switch **1032** or demultiplexer that selectively couples the LO **1030** to one of the receive front end **1022** or transmit front end **1022** so as to be synchronized to the state of the T/R switch **1010**.

Typically, the various elements shown in FIG. **10** are controlled by a processor **1072** that is capable of directing the functioning of one or more of the elements shown in FIG. **10**. (Connections between the various elements are not shown so as not to complicate the diagram.) Typically the operation of the processor **1072** is accomplished with reference to one or more storage media, such as a memory **1074**. The functionality of all or portions of one or more of the elements can be implemented as one or more computer readable instructions encoded on one or more storage media.

FIG. **11** illustrates an advanced technology frame structure **1100** incorporating several aspects discussed above. In particular, the frame structure **1100** includes a legacy downlink sub-subframes **1110** that spans a legacy frequency bandwidth **1112**. The frame structure **1100** also includes two advanced mode downlink sub-subframes **1120a** in **1120b** which occur at a fixed offset from one another. For example, in FIG. **11**, the sub-subframes **1120** occur at 2.5 ms intervals. The advanced mode downlink sub-subframes also include stand-alone headers **1122** which obviate the need for

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advanced mode client stations to monitor a portion of the legacy subframes. In addition, the frame **1100** includes two advanced mode downlink sub-subframe portions **1130a** **1130b**, which occur at the same time as the legacy downlink sub-subframe **1110** and use a portion of the advanced mode frequency bandwidth **1124**. Likewise the frame **1100** includes two advanced mode uplinks sub-subframe portions **1132a** and **1132b** which occur at the same time as the legacy uplink subframe **1114** and use a portion of the advanced mode frequency bandwidth **1124**.

FIG. **12** illustrates a process **1200** for creating an integrated, backwards compatible advanced technology frame structure. In block **1210**, a frame header is created, such as the frame header **206** of FIG. **2**, which includes the advanced mode allocations, or the header **120** of FIG. **1b**, which includes a pointer to the advanced technology resource map **124** within the advanced mode sub-subframe **118**. In block **1230**, a corresponding frame is created. A portion of the frame is populated with data using a first technology format, such as, for example, the legacy format described herein, and a portion is populated with data using a second technology form, such as, for example, the advanced mode format described herein. In block **1240**, the resulting frame is transmitted over a wireless network. In one embodiment, blocks **1210**, **1220** and **1230** are performed by the legacy resource mapper **942**, the advanced resource mapper **944**, the legacy DL signal processor **952**, the advanced DL signal processor **954**, and the scheduler **970**. In one embodiment, block **1240** is performed by the transmitter **960** and the antenna **902**.

FIG. **13** illustrates a process **1300** for receiving an integrated, backwards compatible advanced frame structure at a client station. In block **1310**, a frame header in a first technology format is received. In block **1320**, the frame header is parsed to determine the location of an alternate technology region. In block **1330**, a grant of resources within the alternate technology region is granted according to a grant message received within the alternate technology format region. In block **1340**, data is transmitted or received in the alternate technology format within the alternate technology region according to the grant. The process **1300** illustrates operation at the client station in a system using a frame structure such as the one shown in FIG. **1b** where in the advanced technology resource map **124** is included within the advanced mode region. A similar process can be used to receive a frame according to the format shown in FIG. **2**. For example, the client station receives a resource grant message within the first technology format region granting allocations within the alternate technology region. The process shown in FIG. **13** may be implemented, for example, by the client station of FIG. **10**.

FIG. **14** illustrates a process **1400** for creating an integrated, backwards compatible advanced frame structure for transmission over a wireless link. In block **1410**, a base station, such as the one shown in FIG. **9**, creates a subframe designated, according to a first technology standard, as a downlink portion of a frame. For example the first technology standard may be IEEE 802.16e. In block **1420**, a base station time division multiplexes the downlink subframe portion into a sub-subframe compliant with the standard and an advanced technology sub-subframe. For example, an uplink, advanced mode sub-subframe is inserted into the downlink subframe. The alternate technology may be an IEEE 802.16m type or LTE type technology. Among other structures, the resulting structure may resemble the frame structure **1100** shown in FIG. **11** and may be implemented by, for example, a base station implemented in accordance

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with FIG. **9**. In another example, an advanced mode downlink sub-subframe is inserted into a standard-compliant uplink subframe.

FIG. **15** illustrates a process **1500** for using a system that includes both advanced mode enabled base station transmitters and legacy only base station transmitters. In block **1510**, a first base station transmitter transmits a downlink subframe beginning at time A and ending at time B. The downlink subframe includes a downlink legacy technology region beginning at time B and a downlink advanced technology region ending at time C. Time C is between time A and time B. In block **1520**, a neighboring base station transmitter transmits a limited downlink subframe starting at time A and ending at or before time C. The limited downlink subframe does not include any advanced mode regions. In block **1530**, a receiver corresponding to the first base station transmitter receives uplink data in an advanced technology region beginning at time C and ending at time B. The neighboring base station neither transmits nor receives between time C and B.

FIG. **16** shows a process **1600** for using a system that includes both advanced mode enabled base stations and legacy only base stations. In block **1610**, a first base station receives a first uplink communication from a client station operating according to a first technology format. The first uplink communication is received between time A and B. In block **1620**, the first base station receives a second uplink communication from a second client station after time B and before time C, wherein the second client station operates in accordance with a second technology format. In block **1630**, a neighboring base station receives, between the time A and B and between time B and C, a plurality of uplink communications from a plurality of client stations operating according to the first technology format.

As used herein, the term coupled or connected is used to mean an indirect coupling as well as a direct coupling or connection. Where two or more blocks, modules, devices, or apparatus are coupled, there may be one or more intervening blocks between the two coupled blocks.

The steps of a method, process, or algorithm described in connection with the embodiments disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. The steps of a method, process, or algorithm may be embodied in a software module as one or more processor or computer readable instructions encoded in a storage medium executed by a processor, or in a combination of hardware and software. The various steps or acts in a method or process may be performed in the order shown, or may be performed in another order. Additionally, one or more process or method steps may be omitted or one or more process or method steps may be added to the methods and processes. An additional step, block, or action may be added in the beginning, end, or intervening existing elements of the methods and processes.

The above description of the disclosed embodiments is provided to enable any person of ordinary skill in the art to make or use the disclosed embodiments. Various modifications to these embodiments will be readily apparent to those of ordinary skill in the art, and the generic principles defined herein may be applied to other embodiments without departing from the scope of the disclosure.

What is claimed is:

1. A method of orthogonal frequency division multiple access (OFDMA) communication, the method comprising: transmitting, from a base station, a first downlink subframe in a first downlink frequency band according to a first technology format, the first downlink subframe



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beginning at a first time and ending at a second time, the first downlink subframe comprising a preamble for synchronization, a downlink allocation table (DL-MAP) associated with the first downlink subframe, and an uplink allocation table (UL-MAP);

transmitting, from the base station, at least one second downlink subframe in a second downlink frequency band according to a second technology format, the at least one second downlink subframe beginning after the second time and ending at a third time;

transmitting, from a first client station, a first uplink subframe in a first uplink frequency band according to the first technology format, the first uplink subframe beginning after the third time and ending at a fourth time;

transmitting, from a second client station, at least one second uplink subframe in a second uplink frequency band according to the second technology format, the at least one second uplink subframe beginning after the fourth time and ending at a fifth time.

2. The method of claim 1, wherein the first downlink frequency band is the same as the second downlink frequency band.

3. The method of claim 1, wherein the first uplink frequency band is the same as the second uplink frequency band.

4. The method of claim 1, wherein the first downlink frequency band is the same as the second downlink frequency band, and wherein the first uplink frequency band is the same as the second uplink frequency band but is different than the frequency band of the first downlink frequency band and the second downlink frequency band.

5. The method of claim 1, wherein the first downlink frequency band, the second downlink frequency band, the first uplink frequency band and the second uplink frequency band are each different frequency bands than each other.

6. The method of claim 1, wherein the first downlink frequency band, the second downlink frequency band, the first uplink frequency band and the second uplink frequency band are the same frequency band.

7. The method of claim 6, wherein the UL-MAP is associated with a time interval occurring between the third time and the fourth time.

8. The method of claim 4, wherein the UL-MAP is associated with a time interval occurring after the fifth time.

9. The method of claim 1, wherein:

- the first downlink frequency band is part of the second downlink frequency band;
- the second downlink frequency band is wider than the first downlink frequency band;
- the first uplink frequency band is the same as the first downlink frequency band; and
- the second uplink frequency band is the same as the second downlink frequency band.

10. The method of claim 1, wherein:

- the first downlink frequency band is part of the second downlink frequency band;
- the second downlink frequency band is wider than the first downlink frequency band;
- the first uplink frequency band is part of the second uplink frequency band; and
- the second uplink frequency band is wider than the first uplink frequency band.

11. The method of claim 9, wherein the UL-MAP is associated with a time interval between the third time and the fourth time.

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12. The method of claim 10, wherein the UL-MAP is associated with a time interval that occurs after the fifth time.

13. The method of claim 1, further comprising dynamically adjusting a timing of an occurrence of at least one of the second time, the third time, the fourth time and the fifth time.

14. The method of claim 1, further comprising transmitting, after the second time, a stand-alone frame header associated with the second technology format.

15. A wireless orthogonal frequency division multiple access (OFDMA) system, the system comprising:

- a base station comprising a transmitter configured to:
  - transmit a first downlink subframe in a first downlink frequency band according to a first technology format, the first downlink subframe beginning at a first time and ending at a second time, the first downlink subframe comprising a preamble for synchronization, a downlink allocation table (DL-MAP) associated with the first downlink subframe, and an uplink allocation table (UL-MAP); and
  - transmit at least one second downlink subframe in a second downlink frequency band according to a second technology format, the at least one second downlink subframe beginning after the second time and ending at a third time;
- a first client station comprising a transmitter configured to:
  - transmit a first uplink subframe in a first uplink frequency band according to the first technology format, the first uplink subframe beginning after the third time and ending at a fourth time; and
- a second client station comprising a transmitter configured to:
  - transmit at least one second uplink subframe in a second uplink frequency band according to the second technology format, the at least one second uplink subframe beginning after the fourth time and ending at a fifth time.

16. The wireless OFDMA system of claim 15, wherein the first downlink frequency band is the same as the second downlink frequency band.

17. The wireless OFDMA system of claim 15, wherein the first uplink frequency band is the same as the second uplink frequency band.

18. The wireless OFDMA system of claim 15, wherein the first downlink frequency band is the same as the second downlink frequency band, and wherein the first uplink frequency band is the same as the second uplink frequency band but is different than the frequency band of the first downlink frequency band and the second downlink frequency band.

19. The wireless OFDMA system of claim 15, wherein the first downlink frequency band, the second downlink frequency band, the first uplink frequency band and the second uplink frequency band are each different frequency bands than each other.

20. The wireless OFDMA system of claim 15, wherein the first downlink frequency band, the second downlink frequency band, the first uplink frequency band and the second uplink frequency band are the same frequency band.

21. The wireless OFDMA system of claim 20, wherein the UL-MAP is associated with a time interval occurring between the third time and the fourth time.

22. The wireless OFDMA system of claim 18, wherein the UL-MAP is associated with a time interval occurring after the fifth time.

**23.** The wireless OFDMA system of claim **15**, wherein:  
the first downlink frequency band is part of the second  
downlink frequency band;

the second downlink frequency band is wider than the first  
downlink frequency band;

the first uplink frequency band is the same as the first  
downlink frequency band; and

the second uplink frequency band is the same as the  
second downlink frequency band.

**24.** The wireless OFDMA system of claim **15**, wherein:  
the first downlink frequency band is part of the second  
downlink frequency band;

the second downlink frequency band is wider than the first  
downlink frequency band;

the first uplink frequency band is part of the second uplink  
frequency band; and

the second uplink frequency band is wider than the first  
uplink frequency band.

**25.** The wireless OFDMA system of claim **23**, wherein the  
UL-MAP is associated with a time interval between the third  
time and the fourth time.

**26.** The wireless OFDMA system of claim **24**, wherein the  
UL-MAP) is associated with a time interval that occurs after  
the fifth time.

**27.** The wireless OFDMA system of claim **15**, wherein the  
base station is further configured to dynamically adjust a  
timing of an occurrence of at least one of the second time,  
the third time, the fourth time and the fifth time.

**28.** The wireless OFDMA system of claim **15**, wherein the  
transmitter of the base station is further configured to  
transmit, after the second time, a stand-alone frame header  
associated with the second technology format.

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